

# APOLLO

## GUIDANCE, NAVIGATION AND CONTROL

Submitted by: M. H. Hamilton Date: 12-30-69  
M. H. HAMILTON, DIRECTOR, MISSION PROGRAM DEVELOPMENT  
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved: R. A. Larson Date: 12-30-69  
R. A. LARSON, LUMINARY PROJECT MANAGER  
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved: R. H. Battin Date: 12/31/69  
R. H. BATTIN, DIRECTOR, MISSION DEVELOPMENT  
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved: D. G. Hoag Date: 2 Jan 70  
D. G. HOAG, DIRECTOR  
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved: R. R. Ragan Date: 2 Jan 70  
R. R. RAGAN, DEPUTY DIRECTOR  
INSTRUMENTATION LABORATORY

E-2471

APOLLO GUIDANCE AND NAVIGATION  
FLOW CHARTS

PROGRAM LUMINARY IC

JANUARY 1970

**MIT INSTRUMENTATION  
LABORATORY**

CAMBRIDGE 39, MASSACHUSETTS

## 12.0 THRUST PROGRAMS

# P40 DPS THRUST

## MAJOR SUBROUTINES AND EXTERNAL ENTRY POINTS

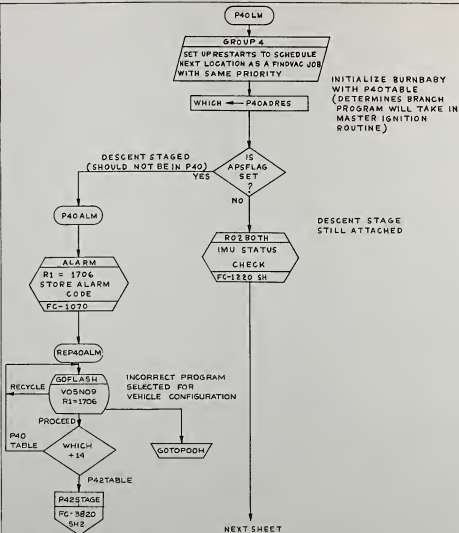
|         |  |       |
|---------|--|-------|
| P40LM   | P40 DPS THRUST PROGRAM                                     | SH. 2 |
| P40SXT4 | CALL ATTITUDE MANEUVER ROUTINE                             | SH. 4 |
| S40.1   | COMPUTE INITIAL THRUST DIRECTION AND VELOCITY TO BE GAINED | SH. 5 |
| S40.2,3 | COMPUTE PREFERRED IMU ORIENTATION                          | SH. 7 |

THE ENCLOSED REPLACEMENT SHEETS WILL UPDATE THE LUMINARY 69 FLOWCHART FC-3800, REV. 0, TO LUMINARY 1A (LUMINARY 99) FLOWCHART FC-3800, REV. 1.

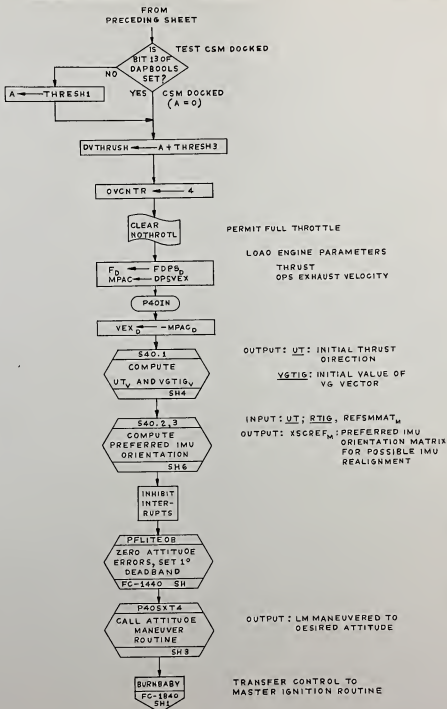
THE EFFECTIVE SHEETS FOR LUMINARY 1A FC-3800, REV. 1 ARE:

|         |        |
|---------|--------|
| SH. 1   | REV. 0 |
| SH. 2   | REV. 1 |
| SH. 3-4 | REV. 0 |
| SH. 5-6 | REV. 1 |
| SH. 7   | REV. 0 |
| SH. 8   | REV. 1 |
| SH. 9   | REV. 0 |

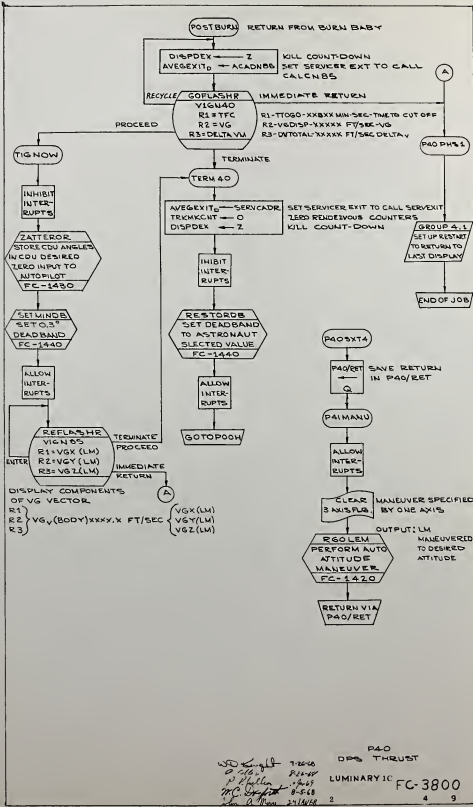
|  |  |   |  |
|--|--|---|--|
| <p>MIT<br/>INSTRUMENTATION LAB<br/>CAMBRIDGE, MASS.</p>  |  | <p>APPLIED<br/>GUIDANCE AND NAVIGATION</p>  |  |
| <p>DRAWN <i>[Signature]</i> <i>[Date]</i> MAY 69<br/>           PREP'D <i>[Signature]</i> <i>[Date]</i> MAY 69<br/>           ANALYST <i>[Signature]</i> <i>[Date]</i> MAY 69<br/>           DOCUM <i>[Signature]</i> <i>[Date]</i> MAY 69<br/>           APPR'D <i>[Signature]</i> <i>[Date]</i> MAY 69</p> |  | <p>P40<br/>DPS THRUST<br/>LUMINARY 1C<br/>FC-3800<br/>REV. 2<br/>SHEET 1 OF 9</p> |  |



| TABLE USED BY MASTER<br>IGNITION ROUTINE | WHICH<br>INDEX |
|--|----------------|
|--|----------------|



|  |   |                                  |                |
|--|---|----------------------------------|----------------|
| MEET<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.  |   | DATE: 11/11/68<br>BY: 11/11/68   |                |
| DESIGN: <i>R. J. Smith</i><br>DRAWN: <i>R. J. Smith</i><br>CHECKED: <i>R. J. Smith</i><br>APPROVED: <i>R. J. Smith</i> | 25 OCT 68<br>11/12/68<br>11/12/68<br>11/12/68 | P40<br>OPS THRUST<br>LUMINARY IC | FC-3800<br>3 9 |

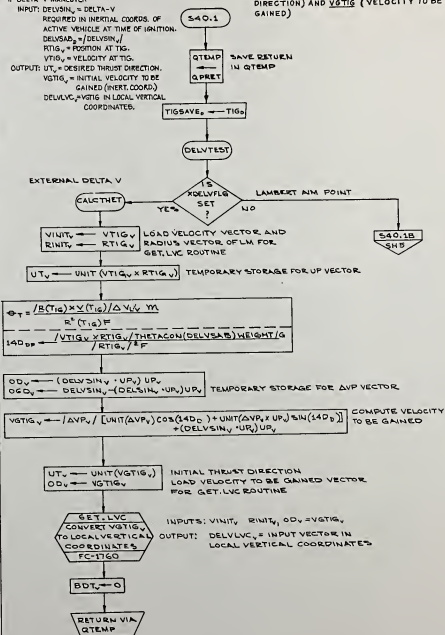


P40  
DPS THRUST  
LUMINARY IC EC-3800

4 9

INPUT: DELVSIN<sub>0</sub> = DELTA-V  
REQUIRED IN INERTIAL COORDS. OF  
ACTIVE VEHICLE AT TIME OF IGNITION.  
DELVSAD<sub>2</sub> = /DELVSIN<sub>0</sub>/  
RTIG<sub>0</sub> = POSITION AT TIG.  
VTIG<sub>0</sub> = VELOCITY AT TIG.  
OUTPUT: UT<sub>0</sub> = DESIRED THRUST DIRECTION.  
VGTIG<sub>0</sub> = INITIAL VELOCITY TO BE  
GAINED (INERT. COORD.)  
DELVLVC<sub>0</sub> = VGTIG IN LOCAL VERTICAL  
COORDINATES.

COMPUTE INITIAL VALUE OF UT (THRUST DIRECTION) AND VGTIG (VELOCITY TO BE GAINED)



P40  
DPS THRUST

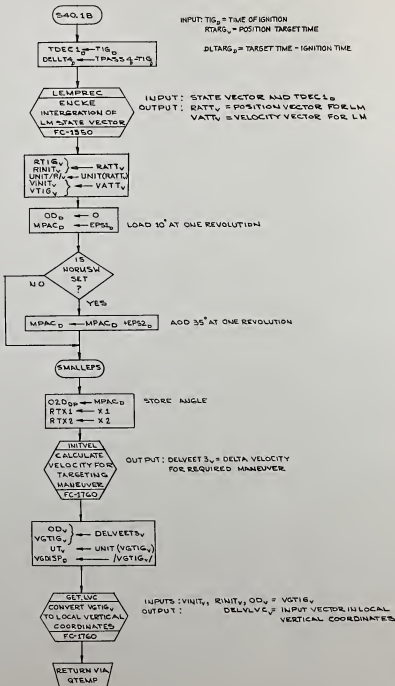
WDC 7-29-68  
P. Galt 8-26-68  
P. R. 8-29-68  
W.C. 8-5-68  
J. R. 8-10-68  
16 May 69

LUMINARY IC

FC-3800

2 5 9

# LAMBERT AIMPOINT MANEUVER



P40  
DPS THRUST

LUMINARY IC

FC-3800

2

6

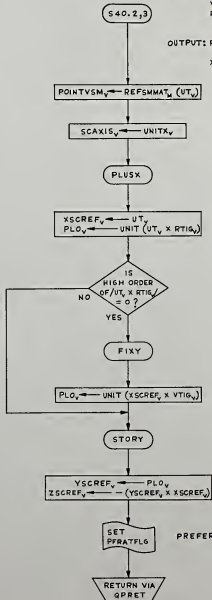
9

W.D. Knight 7-27-68  
 J. R. Knight 10-16-68  
 J. R. Knight 11-16-68  
 J. R. Knight 1-5-68  
 J. R. Knight 1-18-68  
 J. R. Knight 1-18-68



COMPUTE PREFERRED IMU ORIENTATION MATRIX  
FOR POSSIBLE IMU REALIGNMENT

INPUT:  $UT_v$  = INITIAL THRUST DIRECTION.  
 $RTIG_v$  = RADIUS VECTOR OF LM.  
 $VTIG_v$  = VELOCITY VECTOR OF LM.  
 $REFSMAT_M$  = TRANSFORMATION MATRIX  
 BETWEEN BRC SYSTEM AND STABLE  
 MEMBER COORDINATE SYSTEM.  
 OUTPUT:  $POINTSM_v$  = LM THRUST DIRECTION IN SM  
 COORDINATE.  
 $XSCREF_M$  = PREFERRED IMU ORIENTATION  
 MATRIX.



TRANSFORM THRUST DIRECTION  
TO SM COORDINATES.

PREFERRED ATTITUDE COMPUTED

|  |  |  |  |
|--|--|--|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.   |  | APOLLO<br>GUIDANCE AND NAVIGATION                    |  |
| DESIGNED BY: <i>[Signature]</i><br>DRAWN BY: <i>[Signature]</i><br>CHECKED BY: <i>[Signature]</i><br>APPROVED BY: <i>[Signature]</i> |  | P40<br>DPS THRUST<br>LUMINARY IC<br>FC-3800<br>REV 2 |  |

## SUBROUTINES

IN THIS CHART

P40 SXT4

S40.1

S40.2,3

CALL ATTITUDE MANEUVER ROUTINE  
 COMPUTE INITIAL THRUST DIRECTION AND VELOCITY TO BE GAINED  
 COMPUTE PREFERRED IMU ORIENTATION

## ON OTHER CHARTS

R02 BOTH

ALARM

PF LITE DB

ZATTEROR

SET MINDB

RESTOR DB

R60 LEM

SET LVC

LEMPREC

INITVEL

IMU STATUS CHECK

STORE ALARM CODE

ZERO ATTITUDE ERRORS, SET 1° DEADBAND

STORE CDU DESIRED, ZERO INPUT TO AUTOPILOT

SET 0.3° DEADBAND

SET DEADBAND TO ASTRONAUT SELECTED VALUE

PERFORM AUTO ATTITUDE MANEUVER

CONVERT INPUT VECTOR TO LOCAL VERTICAL COORDINATES

ENCKE INTEGRATION OF LM STATE VECTOR

CALCULATE VELOCITY FOR TARGETING MANEUVER

FLAGS MEANING SET CLEARED TESTED

|            |  |      |      |      |
|------------|--|------|------|------|
| NO THROT   | SET - INHIBIT FULL THROTTLE<br>CLEARED - PERMIT FULL THROTTLE                        |      | SH 3 |      |
| 3 AXIS FLG | SET - MANEUVER SPECIFIED BY THREE AXES<br>CLEARED - MANEUVER SPECIFIED BY ONE AXIS   |      | SH 4 |      |
| VDLV FLG   | SET - EXTERNAL DELTA V VS COMPUTATION<br>CLEARED - LAMBERT (AIMPOINT) VS COMPUTATION |      |      | SH 5 |
| UORM SW    | SET - UNIT NORMAL COMPUTED<br>CLEARED - UNIT NORMAL NOT COMPUTED                     |      |      | SH 6 |
| PPRAT FLG  | SET - PREFERRED ATTITUDE COMPUTED<br>CLEARED - PREFERRED ATTITUDE NOT COMPUTED       | SH 7 |      |      |

DISPLAYS MEANING USED

|        |   |  |      |
|--------|---|--|------|
| V16N40 | R1 - TTGO - XXBXX MIN-SEC-TIME TO CUTOFF<br>R2 - VGDISP - XXXX.X FT/SEC-VELOCITY TO BE GAINED<br>R3 - DVTOTAL - XXXX.X FT/SEC-TOTAL DELTA V   |  | SH 4 |
| V16N85 | R1 } V <sub>G</sub> (BODY) XXXX.X FT/SEC { V <sub>OX</sub> (LM)<br>R2 } V <sub>G</sub> (LM) { V <sub>OY</sub> (LM)<br>R3 } V <sub>G</sub> (LM) { V <sub>OZ</sub> (LM) } COMPONENTS OF V <sub>G</sub> VECTOR |  | SH 4 |

ALARM MEANING USED

|      |  |      |
|------|--|------|
| 1706 | INCORRECT PROGRAM SELECTED FOR VEHICLE CONFIGURATION | SH 2 |
|------|--|------|

ERASABLE MEANING UNITS SCALING

|                     |                                |             |                 |
|---------------------|--------------------------------|-------------|-----------------|
| VINIT <sub>v</sub>  | VELOCITY AT TIME OF IGNITION   | M/CSC       | 2 <sup>7</sup>  |
| RINIT <sub>v</sub>  | POSITION AT TIME OF IGNITION   | M           | 2 <sup>29</sup> |
| VSTIG <sub>v</sub>  | INITIAL VELOCITY TO BE GAINED  | M/CSEC      | 2 <sup>7</sup>  |
| UT <sub>v</sub>     | DESIRED THRUST DIRECTION       | UNIT VECTOR | 2 <sup>1</sup>  |
| XSCREF <sub>v</sub> | WINGS-LEVEL HEAD-UP            | UNIT VECTOR | 2 <sup>1</sup>  |
| YSCREF <sub>v</sub> | LM ORIENTATION IN              | UNIT VECTOR | 2 <sup>1</sup>  |
| ZSCREF <sub>v</sub> | REFERENCE COORDINATES          | UNIT VECTOR | 2 <sup>1</sup>  |
| F <sub>D</sub>      | ENGINE THRUST                  | M-NEWTONS   | 2 <sup>7</sup>  |
| TDEAY <sub>D</sub>  | ATTAIL-OFF TIME TIME OF ENGINE | CSEC        | 2 <sup>28</sup> |

\* M-NEWTONS = 10<sup>6</sup> NEWTONS

P40

DPS THRUST

LUMINARY IC

FC-3800

8 9

W.D. KIGHT 7-26-68

J. C. Kight 8-26-68

J. C. Kight 11-2-68

J. C. Kight 8-5-68

J. C. Kight 2-18-68

16 May 69

| FIXED<br>CONSTANTS     | MEANING                          | PHYSICAL VALUE<br>f UNITS         | STORED VALUE<br>f UNITS      | SCALING         |
|------------------------|----------------------------------|-----------------------------------|------------------------------|-----------------|
| FDP5 <sub>D</sub>      | DPS ENGINE THRUST                | 9712.5 POUNDS                     | 4.319223105<br>M-NEWTONS*    | 2 <sup>7</sup>  |
| THETA CON <sub>D</sub> | $\frac{1}{16}$ CONVERSION FACTOR | $\frac{1}{16}$ $\frac{1}{16}$ RAD | .01630989 $\frac{1}{16}$ RAD | 2 <sup>8</sup>  |
| TOECAT <sub>D</sub>    | DPS ENGINE AT<br>TAIL-OFF TIME   | 0.08 SEC                          | - 8 C SEC                    | 2 <sup>24</sup> |

\*M-NEWTONS = 10<sup>-3</sup> NEWTONS

# ADDED FLAG FOR P40 DPS THRUST

| FLAG                     | MEANING WHEN SET | MEANING WHEN CLEAR | WHERE<br>SET | WHERE<br>Cleared | WHERE<br>TESTED |
|--------------------------|------------------|--------------------|--------------|------------------|-----------------|
| BIT 13<br>OF<br>DAPBOOLS | C5M DOCKED       | C5M IS NOT DOCKED  |              |                  | SH3             |
| APSFLAG                  | ASCENT STAGE     | DESCENT STAGE      |              |                  | SH2             |

P40  
 DPS THRUST  
 LUMINARY IC  
 FC-3800  
 2  
 9 9  
 8-5-68  
 8-25-68  
 10 Jan 69  
 8-5-68  
 27 Jan 69  
 16 Aug 69

# P41 RCS THRUST

## MAJOR SUBROUTINES ON THIS CHART

|          |   |     |
|----------|---|-----|
| P41LM    | P41 RCS THRUST PROGRAM                        | SH2 |
| CALCN85  | CALL VG CALCULATION                           | SH5 |
| S41.1    | TRANSFORM VECTOR FROM REF. COORD TO BODY AXIS | SH5 |
| UPDATEVG | UPDATE VG CALCULATION                         | SH5 |

|  |                                 |                                    |  |
|--|---------------------------------|------------------------------------|--|
| RIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                                 | APPLIED<br>GUIDANCE AND NAVIGATION |  |
| DRAWN <i>[Signature]</i> 30 MAY 68             |                                 | P41 RCS THRUST                     |  |
| DESIGNED <i>[Signature]</i> 27 JUN 68          | BY <i>[Signature]</i> 27 JUN 68 | LUMINARY IC                        |  |
| APPROVED <i>[Signature]</i> 27 JUN 68          | BY <i>[Signature]</i> 27 JUN 68 | FC-3810                            |  |

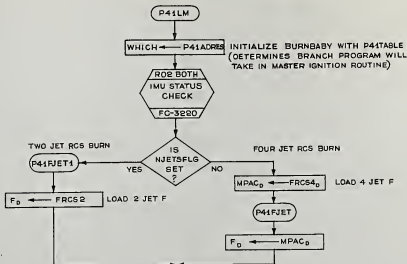
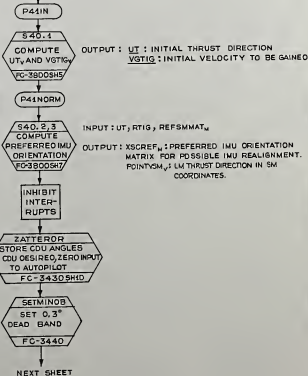


TABLE USED BY MASTER  
IGNITION ROUTINE

| P41TABLE | IGNITION ROUTINE | WHICH INDEX |
|----------|------------------|-------------|
| TCF      | P415POT          | (5)         |
| DEC      | -1               | (6)         |
| 2CADR    | CALCN85          | (7)         |
| TCF      | COMMON           | (41)        |
| TCF      | TIGTASK          | (42)        |



P41  
RCS THRUST

30 JUL 68

LUMINARY TO

FC-3810

*P. M. D. 10/1/68*  
*2-10-68*  
*10-10-68*  
*26-10-68*  
*30 JUL 68*

1

2 14

FROM PRECEDING SHEET



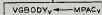
OUTPUT: LM MANEUVERED TO  
DESIRED ATTITUDE



LOAD VECTOR FOR S41.1 ROUTINE



INPUT: MPAC<sub>V</sub>; INPUT VECTOR, REFSMMAT<sub>M</sub>  
OUTPUT: MPAC<sub>V</sub> = TRANSFORMED VECTOR  
IN LM BODY AXIS COORDINATES



STORE VG VECTOR FOR DISPLAY

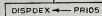


DISPLAY COMPONENTS OF  
VG VECTOR

R1 -  
R2 -  
R3 -

VGBODY<sub>V</sub> - XXXX.X FT/SEC

{ VGX(LM)  
VGY(LM)  
VGZ(LM) } - COMPONENTS  
OF VG VECTOR



SCHEDULE DISPLAY OF  
V16N85 VG VECTOR



TRANSFER CONTROL TO  
MASTER IGNITION ROUTINE

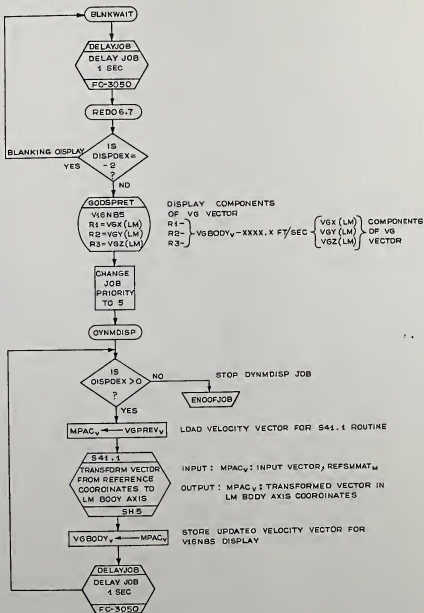
P41  
RCS THRUST

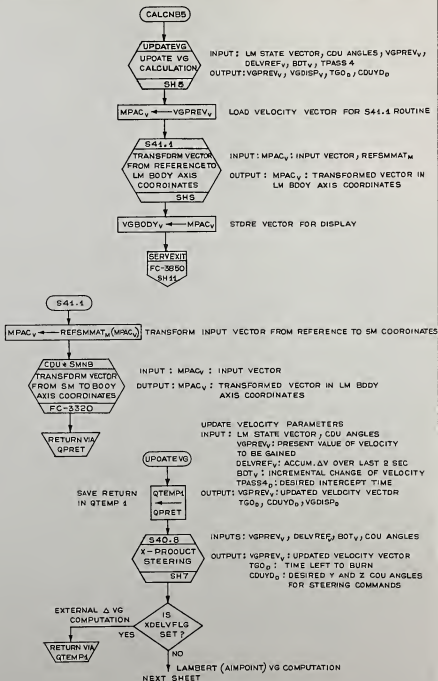
FC-3810

*John A. Moore*  
30 JUL 68  
8:26 PM  
1034-01  
2644-01  
22 JUL 68

LUMINARY 1C  
1

3 14





P41  
RCS THRUST

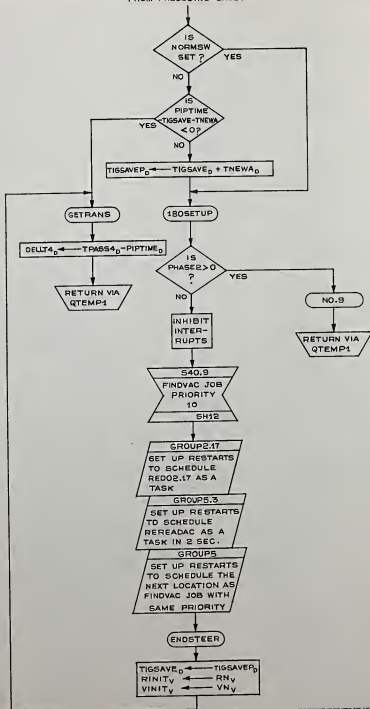
2 JUL 68  
2 AUG 68  
19 SEP 68  
24 MAR 69

LUMINARY IC  
FC-3810

5 14



FROM PRECEDING SHEET



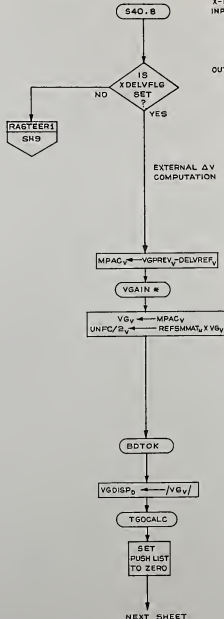
RECEIVED  
INFORMATION LAB  
CAMBRIDGE, MASS.  
DATE: 12/16/67  
BY: [Signature]  
APPROVED: [Signature]  
REVIS: 1

ROLL  
EVIDENCE AND NOTATION  
P41  
RCB THRUST  
DOCUMENT NO  
FC-3810  
DATE: 6 12 68

# X-PRODUCT STEERING

INPUTS : VGPREV<sub>v</sub>: PRESENT VALUE OF VELOCITY  
TO BE GAINED VECTOR  
DELVREF<sub>v</sub>: ACCUMULATED ΔV OVER  
LAST 2 SEC

OUTPUT: VGPREV<sub>v</sub>: UPDATED VALUE OF VELOCITY  
TO BE GAINED VECTOR  
TGO<sub>0</sub>: TIME LEFT TO BURN  
CDUVD<sub>0</sub>: DESIRED Y & Z CDU ANGLES  
FOR STEERING COMMANDS



NEXT SHEET

P41

RCS THRUST

3 JUL 68

8-1668

10/10/68

10/10/68

10/10/68

10/10/68

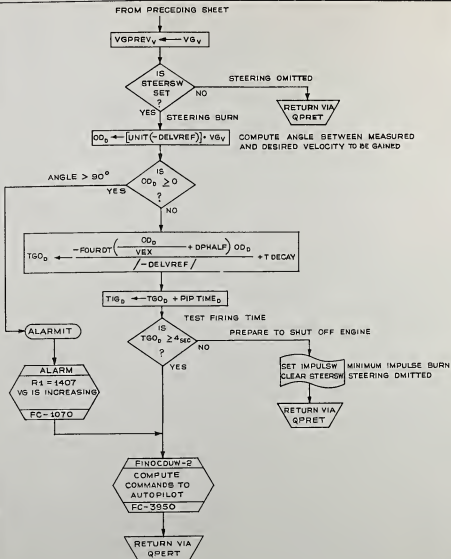
LUMINARY IC

FC-3810

1

7

14

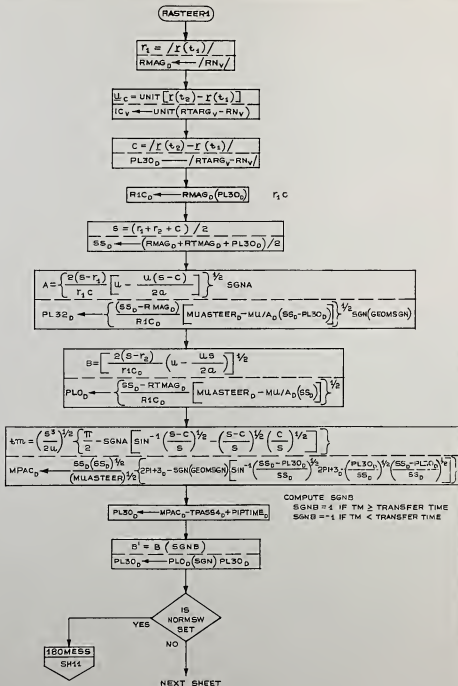


P41  
RCS THRUST

LUMINARY 1C

FC-3810

8 14



|  |   |  |  |
|--|---|--|--|
| MIT<br>INSTRUMENTATION LAB<br>AMPS/SEC MASS  |   | ATSD<br>INSTRUMENTATION LAB<br>P41<br>RCS THRUST<br>LUMINARY IC<br>FC-3810<br>9 14 |  |
| NAME: <i>P. J. Dwyer</i><br>IN AD: <i>Adler</i><br>IN ST: <i>McDonald</i><br>APPRO: <i>John M. Brown</i> | DATE: <i>7-1-66</i><br>TIME: <i>10:00</i><br>BY: <i>John M. Brown</i> | 180MESS<br>SH14  |  |

FROM PRECEDING SHEET

$$PLO_V \leftarrow UNIT(IC_V - UNIT/R/V) PL30_D$$

$$B'UNIT(\underline{L}_C - \underline{L}_R) = B'(\underline{L}_C - R)$$

$$MPAC_V \leftarrow UNIT(IC_V + UNIT/R/V)$$

$$UNIT(\underline{L}_C + \underline{L}_R) = (\underline{L}_C + R)$$

GETVRVG1

$$MPAC_V \leftarrow MPAC_V(PL32_D) + PLO_V$$

$$A'(\underline{L}_C + R) + B'(\underline{L}_C - R)$$

GETVRVG2

$$\underline{Y}_R(t) = A'(\underline{L}_C + R) + B'(\underline{L}_C - R)$$

$$VIPRIME_V \leftarrow MPAC_V$$

ASTREND

$$DELVEET3_V \leftarrow VIPRIME_V - VN_V$$

$$\underline{Y}_R(t) - \underline{Y}(t)$$

FIRSTTIME

MOON SPHERE

NO

IS  
RTX2=0  
?

YES

EARTH SPHERE

GETGOBL

$$PL34_D \leftarrow 1/RN_V^2$$

$$\underline{Y}_G(t) = \underline{Y}_R(t) + \underline{g}_p(t)(t - t_{IG}) - \underline{Y}(t)$$

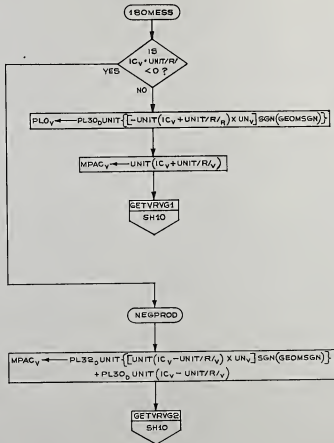
$$MPAC_V \leftarrow UNITGOBL_V(PITIME_V - GOBLTIME_D) \frac{EARTHMU2 + DELVEET3}{PL34_D}$$

NOGOBL

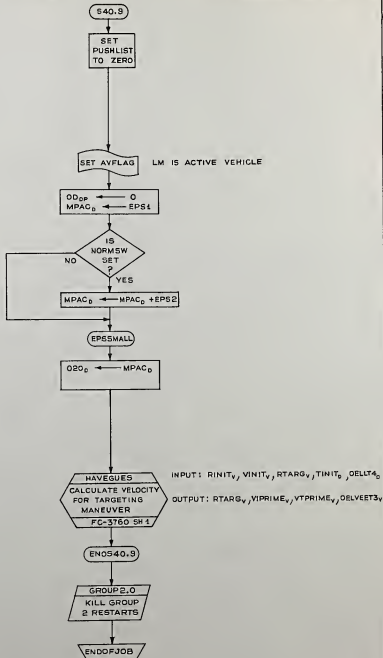
$$DELVEET3_V \leftarrow MPAC_V$$

VGAIN \*  
SH7

|  |  |                                |  |
|--|--|--------------------------------|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | AI 810<br>CELESTIAL NAVIGATION |  |
| DRAWN: <i>[Signature]</i>                      |  | P41                            |  |
| CHECKED: <i>[Signature]</i>                    |  | RCS THRUST                     |  |
| ANALYST: <i>[Signature]</i>                    |  | LUMINARY IC                    |  |
| CITY: <i>[Signature]</i>                       |  | DOCUMENT NO.                   |  |
| APPROV: <i>[Signature]</i>                     |  | FC-3810                        |  |
|  |  | SHEET 40 OF 44                 |  |



|   |   |   |   |
|---|---|---|---|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE MASS    |   | AFOLIO<br>ORIGIN AND VALIDATION                 |   |
| 24 JAN 68<br>12 FEB 68<br>25 MAR 68<br>1 APR 68 | <i>P. M. Bickel</i><br><i>W. C. Sullivan</i><br><i>McBride</i><br><i>W. C. Sullivan</i> | 24 JAN 68<br>12 FEB 68<br>25 MAR 68<br>1 APR 68 | P41<br>RCS THRUST<br>LUMINARY IC<br>DOCUMENT NO<br><b>FC-3810</b><br>11 OF 14 |



P41  
RCS THRUST

LUMINARY IC

FC-3810

12 14

ON THIS CHART

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S41.1  TRANSFORM VECTOR FROM REF. COORDINATES TO BODY AXIS
CALCN85 CALL VG CALCULATION UPDATE
UPDATEVG UPDATE VG CALCULATION
S40.8   X=PRODUCT STEERING
S40.8   COMPUTE VELOCITY, VELOCITY-TO-BE-GAINED AND B VECTORS

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ROEBOTH    IMU STATUS CHECK
S40.1      COMPUTE UT AND VGTG VECTORS
S40.2,3    COMPUTE PREFERRED IMU ORIENTATION
ZATTEROR   STORE CDU ANGLES IN CDU DESIRED, ZERO INPUT TO AUTOPILOT
SETMINDB   SET 0.3" DEADBAND
P40EXT4     CALL ATTITUDE MANEUVER ROUTINE
DELAYJOB   DELAY SCHEDUOLE JOB
TIMF05PT   LOAD CDUS CORRESPONDING TO PIPTIME IN COUSPOT VECTOR
TRG45NB    TRANSFORM FROM 2'S TO 1'S COORDINATES
XNMN7       TRANSFORM FROM 5M 0 NS COORDINATES
VIST05     CONVERT 1'S COMPLEMENT ANGLES TO 2'S COMPLEMENT ANGLES
ALARM      DISPLAY ALARM CODE
H4RGUES    CALCULATE VELOCITY FOR TARGETING MANEUVER

```

| FLAGS    | MEANING   | SET   | CLEARED | TESTED    |
|----------|---|-------|---------|-----------|
| NJETSFLG | SET-TWO JET RCS BURN<br>CLEARED - FOUR JET RCS BURN                             |       |         | SH 2      |
| XDELVFLG | SET-EXTERNAL DELTAV VG COMPUTATION<br>CLEARED-LAMBERT (AIMPOINT) VG COMPUTATION |       |         | SH 5,7    |
|          |   |       |         |           |
|          |   |       |         |           |
| STEERSW  | SET-STEERING TO BE DONE<br>CLEARED-STEERING OMITTED                             |       | SH 8    | SH 8      |
| IMPULSW  | SET-MINIMUM IMPULSE BURN<br>CLEARED-STEERING BURN                               | SH 8  |         |           |
| AVFLAG   | SET-AVERAGE G (SERVICER) DESIRED<br>CLEARED-AVERAGE G (SERVICER) NOT DESIRED    | SH 12 |         |           |
| NORMSW   | SET-UNIT NORMAL COMPUTED<br>CLEARED-UNIT NORMAL NOT COMPUTED                    |       |         | SH 6,9,12 |

| DISPLAY | MEANING   | USED    |
|---------|---|---------|
| VI6NBS  | $\left. \begin{matrix} R1- \\ R2- \\ R3- \end{matrix} \right\} V_{G_V}(\text{BODY}) \text{ XXXX.X FT/SEC}$ $\left\{ \begin{matrix} VGX(LM) \\ VGY(LM) \\ VGZ(LM) \end{matrix} \right\}$ COMPONENTS OF VG VECTOR | SH 3, 4 |

| ALARMS | MEANING          | USED |
|--------|------------------|------|
| 1407   | VG IS INCREASING | SH B |

400  
 P.N. Dietrich  
 5 AUG 68  
 P. Griffin  
 5-16-68  
 P. Griffin  
 10 AUG 68  
 J.C. Griffin  
 26 AUG 68  
 J. A. Moore  
 24 AUG 68  
 P41  
 RCS THRUST  
 LUMINARY IC  
 FC-3810  
 13 14



| ERASABLES             | MEANING   | UNITS         | SCALING         |
|-----------------------|---|---------------|-----------------|
| F <sub>0</sub>        | THRUST FOR ENGINE USED  | * M - NEWTONS | 2 <sup>7</sup>  |
| VGBOOV <sub>v</sub>   | VELOCITY TO BE GAINED VECTOR (BODY COORDS)  | M/CSEC        | 2 <sup>7</sup>  |
| VG <sub>v</sub>       | VELOCITY TO BE GAINED VECTOR  | M/CSEC        | 2 <sup>7</sup>  |
| AXID <sub>v</sub>     | DESIRED THRUST DIRECTION  | UNIT VECTOR   | 2 <sup>4</sup>  |
| VGDISP <sub>0</sub>   | MAGNITUDE OF VELOCITY TO BE GAINED VECTOR FOR DISPLAY   | M/CSEC        | 2 <sup>7</sup>  |
| VGPREV <sub>v</sub>   | VELOCITY TO BE GAINED VECTOR (PREVIOUS)   | M/CSEC        | 2 <sup>7</sup>  |
| TGD <sub>0</sub>      | TIME LEFT TO BURN   | CSEC          | 2 <sup>28</sup> |
| TIG <sub>0</sub>      | TIME OF IGNITION  | CSEC          | 2 <sup>28</sup> |
| AXIS <sub>v</sub>     | ACTUAL THRUST DIRECTION   | UNIT VECTOR   | 2 <sup>4</sup>  |
| RINIT <sub>v</sub>    | ACTIVE VEHICLE RADIUS VECTOR  | METERS        | 2 <sup>29</sup> |
| VINIT <sub>v</sub>    | ACTIVE VEHICLE VELOCITY VECTOR  | M/CSEC        | 2 <sup>7</sup>  |
| TNIT <sub>0</sub>     | TIME OF STATE VECTOR  | CSEC          | 2 <sup>28</sup> |
| DELT4 <sub>0</sub>    | REMAINING TIME TILL INTERCEPT   | CSEC          | 2 <sup>28</sup> |
| DELVEET3 <sub>v</sub> | VELOCITY TO BE GAINED   | M/CSEC        | 2 <sup>7</sup>  |
| BDTV                  | INCREMENTAL CHANGE OF THE VELOCITY TO BE GAINED VECTOR DUE TO RATE OF CHANGE OF VELOCITY REQUIRED AND GRAVITY VECTOR. THIS IS D <sub>v</sub> FOR EXTERNAL ΔV. | M/CSEC        | 2 <sup>7</sup>  |

\* M - NEWTONS = 10<sup>4</sup> NEWTONS

P41  
RCS THRUST

LUMINARY IC

FC-3810

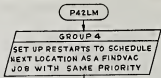
14 14

P42  
APS THRUST

MAJOR SUBROUTINES ON THIS CHART

|          |                                 |     |
|----------|---------------------------------|-----|
| P42LM    | APS THRUST PROGRAM              | SH2 |
| STEERING | SERVICER EXIT FOR STEERING BURN | SH2 |
| GETDT    | STORE INPUT A IN TGO + 1        | SH3 |

|  |        |                                   |          |
|--|--------|-----------------------------------|----------|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |        | APOLLO<br>GUIDANCE AND NAVIGATION |          |
| DRAWN <i>[Signature]</i>                       |        | P42<br>APS THRUST                 |          |
| PROJ <i>[Signature]</i>                        | CHAYAN | LUMINARY IC                       | DOCUMENT |
| ANALYST <i>[Signature]</i>                     | CHAYAN | FC-3820                           |          |
| DOCK <i>[Signature]</i>                        | CHAYAN | SHEET 1 OF 4                      |          |
| APPROD <i>[Signature]</i>                      | CHAYAN |                                   |          |



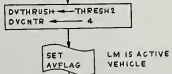
INITIALIZE BURNBABY WITH P42TABLE  
(DETERMINES BRANCH PROGRAM WILL  
TAKE IN MASTER IGNITION ROUTINE)

INCORRECT PROGRAM  
SELECTION FOR  
VEHICLE CONFIGUR-  
ATION



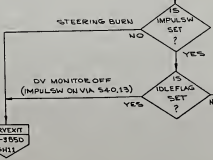
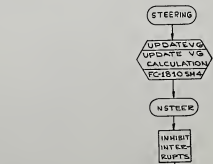
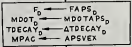
| P42TABLE | VN       | 0640 | (C) |
|----------|----------|------|-----|
| TCF      | WANTAPS  | (1)  |     |
| TCF      | COMFAIL4 | (2)  |     |
| TCF      | GOPOST   | (3)  |     |
| TCF      | TASKOVER | (4)  |     |
| TCF      | P42SPOT  | (5)  |     |
| DEC      | 2640     | (6)  |     |
| 2CADR    | STEERING | (7)  |     |
| TCF      | P40SJUNK | (11) |     |
| TCF      | WANTABIT | (12) |     |
| TCF      | P42IGN   | (13) |     |
| TCF      | P42STAGE | (14) |     |

TABLE USED BY MASTER  
IGNITION TABLE



LOAD APS ENGINE PARAMETERS

FORCE OF ENGINE THRUST  
MASS CHANGE RATE  
AT TAILOFF



W-1  
W-2  
W-3  
W-4  
W-5  
W-6  
W-7  
W-8  
W-9  
W-10  
W-11  
W-12  
W-13  
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W-95  
W-96  
W-97  
W-98  
W-99  
W-100

P42  
APS THRUST

LUMINARY 2

FC-3820

2 4

16 May 59

FROM PRECEDING PAGE

CLEAR IMPULSW  
SET IDLE FLAG

STEERING BURN  
NO DV MONITOR

INHIBIT  
INTER-  
RUPTS

MPAC<sub>0</sub> ← TGO - TIME 2<sub>0</sub>

LOAD TIME OF ENGINE CUT-OFF

TPAGREE  
FORCE SIGN AGREEMENT  
OF CONTENTS OF MPAC  
FC-3150

A ← MPAC + 1

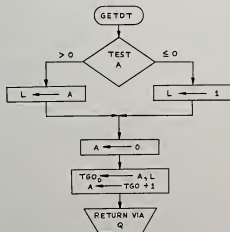
GETDT  
STORE A IN  
TGO + 1  
SH3

ENGOF TSK  
TWIDDLE TASK  
IN C(A) GSEC  
FC-3540 SH16

SCHEDULE TASK TO  
TURN OFF ENGINE

GROUP 4.11  
RESTART  
TASK  
ENGOF TSK  
GROUP 5.3  
RESTART  
TASK  
REREADAG

END OF JOB



W. O. Ringle  
D. G. Gentry  
P. R. Gentry  
H. C. Gentry  
J. B. Gentry

7-25-68  
7-25-68  
7-25-68  
7-25-68

P4-2  
AP3 THRUST

LUMINARY IC

FC-3820

3 4

SUBROUTINES  
ON THIS CHART  
STEERING      SERVICER EXIT FOR STEERING BURN

ON OTHER CHARTS  
R02 BOTH      IMU STATUS CHECK  
UPDATEVS      UPDATEVS CALCULATION  
TPAGREE      FORCE SIGN AGREEMENT OF CONTENTS OF MPACT

| FLAG*    | MEANING   | SET | CLEARED | TESTED |
|----------|---|-----|---------|--------|
| AVFLAG   | SET - LM 1'S ACTIVE VEHICLE<br>CLEARED - CSM 1'S ACTIVE VEHICLE | SH2 |         |        |
| IMPULSW  | SET - MINIMUM IMPULSE BURN<br>CLEARED - STEERING BURN           |     | SH3     | SH2    |
| IDLEFLAG | SET - NO DV MONITOR<br>CLEARED - CONNECT DV MONITOR             | SH3 |         | SH2    |

| ERASABLE | MEANING                | UNITS     | SCALING         | MM-NEWTONS * 10 <sup>4</sup> NEWTONS |
|----------|------------------------|-----------|-----------------|--------------------------------------|
| F        | THRUST FOR ENGINE USED | M-NEWTONS | 2 <sup>7</sup>  |                                      |
| MOOT     | MASS CHANGE RATE       | KG/CSEC   | 2 <sup>3</sup>  |                                      |
| TDECAT   | DELTA-T TAILOFF        | CSEC      | 2 <sup>28</sup> |                                      |
| TGO      | TIME OF ENGINE CUT-OFF | CSEC      | 2 <sup>28</sup> |                                      |

| FIXED<br>CONSTANTS   | MEANING                     | PHYSICAL VALUE<br>UNITS | STORED VALUE<br>UNITS                 | SCALING         |
|----------------------|-----------------------------|-------------------------|---------------------------------------|-----------------|
| FAPS <sub>0</sub>    | APS ENGINE THRUST           | 3500 POUNDS             | 1.0568<br>M-NEWTONS * 10 <sup>4</sup> | 2 <sup>7</sup>  |
| MDOTAPS <sub>0</sub> | APS ENGINE MASS CHANGE RATE | 5.14 KG/SEC             | .0513781593 KG/CSEC                   | 2 <sup>3</sup>  |
| ΔTDECAY <sub>0</sub> | APS ENGINE ΔT TNL-OFF       | -0.07 SEC               | -7 CSEC                               | 2 <sup>28</sup> |

P42  
APS THRUST  
LUMINARY 10  
FC-3820

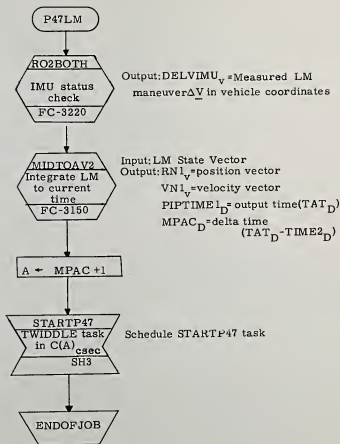
WDC/IGHT 775-60  
Bally 512-69  
Mally 116-11  
775-60  
John B. Rose 25 MAR 69  
10 MAR 69

2 4 4

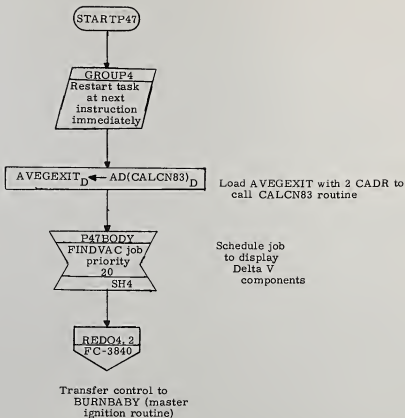
# P47 THRUST MONITOR

P47LM SH. 2  
CALCN83 SH. 5

|   |                  |                                |                         |
|---|------------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                  | APOLLO GUIDANCE AND NAVIGATION |                         |
|   |                  | P47 THRUST MONITOR             |                         |
| DRAWN <i>J. Casco</i>                       | <i>8 AUG 69</i>  |                                |                         |
| PRGRM <i>P. Allen</i>                       | <i>10 MAY 68</i> |                                |                         |
| ANALST                                      |                  | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3830 |
| DOCMR <i>J. C. Dwyer</i>                    | <i>8 AUG 69</i>  |                                |                         |
| APPR'D <i>W. J. ...</i>                     | REV 2            | SHEET 1 OF 5                   |                         |

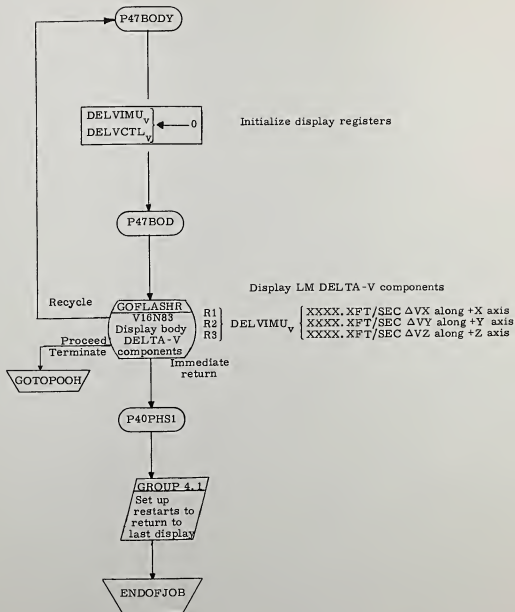


|   |                   |                                |              |
|---|-------------------|--------------------------------|--------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                   | APOLLO GUIDANCE AND NAVIGATION |              |
| DRAWN <i>J. G. J. Jr.</i>                   |                   | P47 Thrust Monitor             |              |
| PRGMR <i>John</i>                           | <i>5 AUG 68</i>   |                                | DOCUMENT NO. |
| ANALST                                      |                   |                                | FC-3830      |
| DOCNR                                       | <i>XC-200-100</i> | LUMINARY 1C                    |              |
| APPR <i>James H. Brown</i>                  | <i>5 AUG 68</i>   | REV 2                          | SHEET 2 OF 5 |

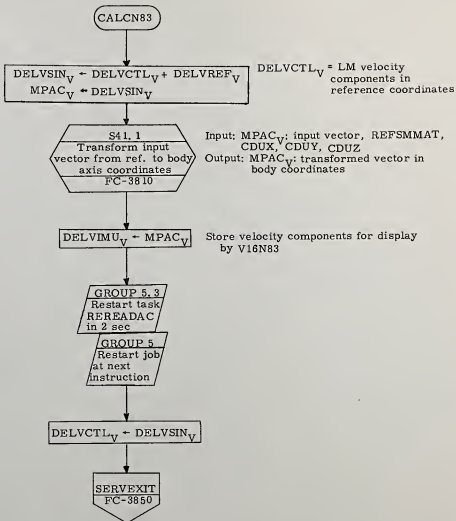


|   |                  |                                |                         |
|---|------------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                  | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN <i>J. Concolle</i>                    |                  | P47 Thrust Monitor             |                         |
| PRGMR <i>P. Allen</i>                       | <i>11 Aug 69</i> | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3830 |
| ANALST                                      |                  |                                |                         |
| DOCMR <i>W. C. ...</i>                      | <i>5 Aug 69</i>  | REV 2                          | SHEET 3 OF 5            |
| APPR'D <i>W. C. ...</i>                     |                  |                                |                         |





| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                | APOLLO GUIDANCE AND NAVIGATION |              |
|---|----------------|--------------------------------|--------------|
| DRAWN                                       | J. Gerold      | P47 Thrust Monitor             |              |
| PRGMR                                       | P. Kelly       | LUMINARY 1C                    | DOCUMENT NO. |
| ANALST                                      |                |                                | FC-3830      |
| DOCMR                                       | J. Gerold      | REV 2                          | SHEET 4 OF 5 |
| APPR'D                                      | David H. Smith |                                |              |



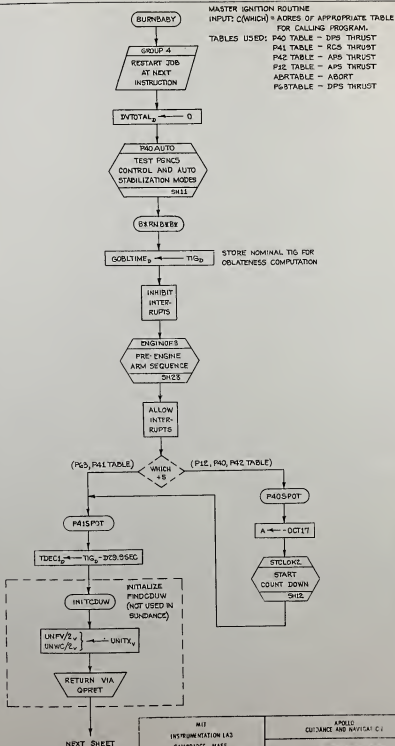
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|---|----------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN <i>J. Sincello</i>                    |                | P47 Thrust Monitor             |                         |
| PRGMR <i>P. Allen</i>                       | <i>5/15/68</i> | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3830 |
| ANALST                                      |                |                                |                         |
| DOCMR <i>W. C. Smith</i>                    | <i>5/15/68</i> | REV 2                          | SHEET 5 OF 5            |
| APPROVED <i>W. C. Smith</i>                 |                |                                |                         |

BURN BABY BURN  
(MASTER IGNITION ROUTINE)

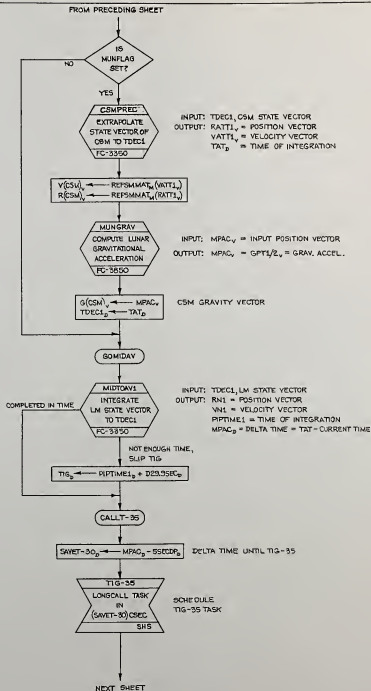
MAJOR SUBROUTINES ON THIS CHART

|           |        |
|-----------|--------|
| BURNBABY  | Sh. 2  |
| ENGINEOF2 | Sh. 13 |
| P40AUTO   | Sh. 11 |
| STCLOCK1  | Sh. 12 |

|   |  |   |         |
|---|--|---|---------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION              |         |
| DRAWN <i>R. Field</i> 4/22/69               |  | Burn Baby Burn<br>(Master Ignition Routine) |         |
| PROGRAM <i>R. Field</i> 4/1/69              |  | DOCUMENT NO.                                |         |
| ANALYST                                     |  | LUMINARY IC                                 | PC-3840 |
| DOCKED <i>R. Field</i> 10/1/69              |  | REV 2                                       |         |
| APPROVED <i>R. Field</i> 10/1/69            |  | SHEET 1 OF 25                               |         |

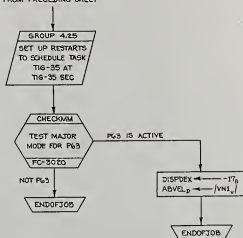


|  |  |   |  |
|--|--|---|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO<br>GUIDANCE AND NAVIGATION           |  |
| DRAWN A. C. WILLIAMS                           |  | 57JUN63                                     |  |
| CHECKED <i>C. Schulerberg</i>                  |  | 6 AUG 63                                    |  |
| ANALYST  |  | LUMINARY IC                                 |  |
| DESIGNED <i>W. C. DeLoach</i>                  |  | 6 AUG 63                                    |  |
| APPROVED <i>W. C. DeLoach</i>                  |  | REV 2                                       |  |
|  |  | BURN BABY BURN<br>(MASTER IGNITION ROUTINE) |  |
|  |  | DOCUMENT NO.<br>FC-3840                     |  |
|  |  | SHEET 2 OF 25                               |  |



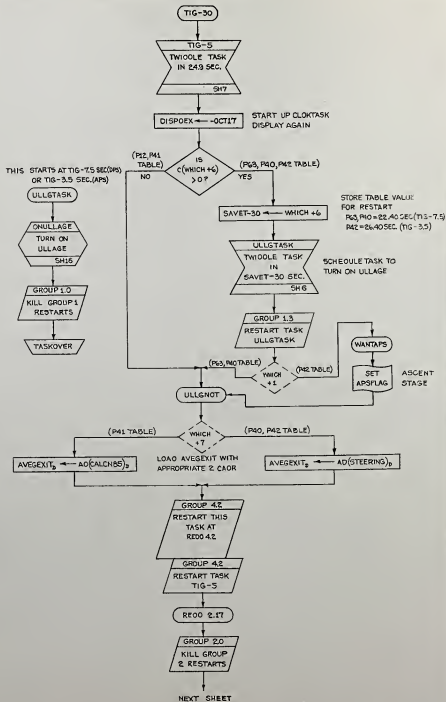
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|--|--|--|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO<br>GUIDANCE AND NAVIGATION            |  |
| DESIGNED BY A.C. WILLIAMS                      |  | BURN BASHY BURN<br>(MASTER IGNITION ROUTINE) |  |
| DRAWN BY J. Subramanyam                        |  | DOCUMENT NO.                                 |  |
| ANALYST  |  | LUMINARY 10                                  |  |
| CHECKED BY J. R. Williams                      |  | FC-3840                                      |  |
| APPROVED BY J. R. Williams                     |  | SHEET 3 of 25                                |  |

FROM PRECEDING SHEET



|  |  |                                   |  |
|--|--|-----------------------------------|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO<br>GUIDANCE AND NAVIGATION |  |
| DRAWN A.C. WILLIAMS                            |  | CHECKED                           |  |
| PREPARED C. Schulenberg                        |  | 6 APR 67                          |  |
| ANALYST  |  | LUMINARY IC                       |  |
| DOCTOR   |  | DOCUMENT NO.                      |  |
| APPROVED                                       |  | FC-3840                           |  |
| REV 2  |  | SHEET 4 OF 25                     |  |





100-100-100-100

100-100-100-100

100-100-100-100

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BURN BABY BURN  
(MASTER IGNITION ROUTINE)

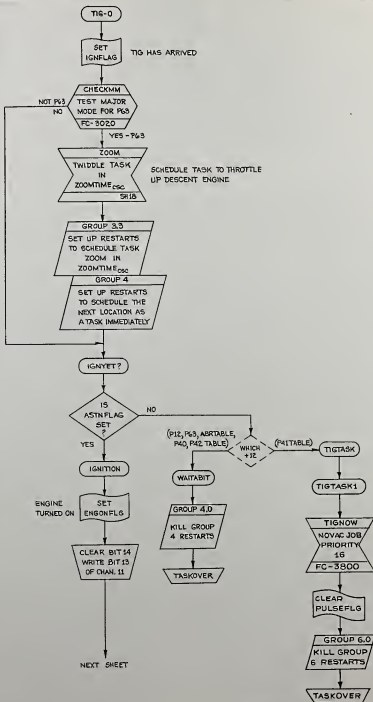
LUMINARY IC

FC-3840

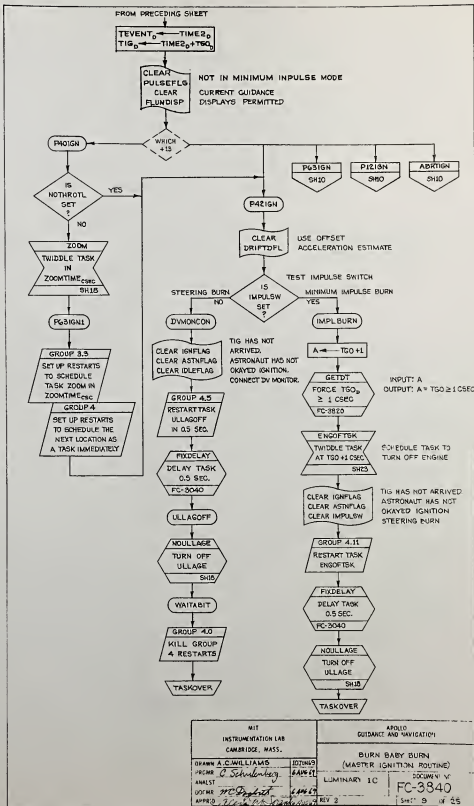
6 35



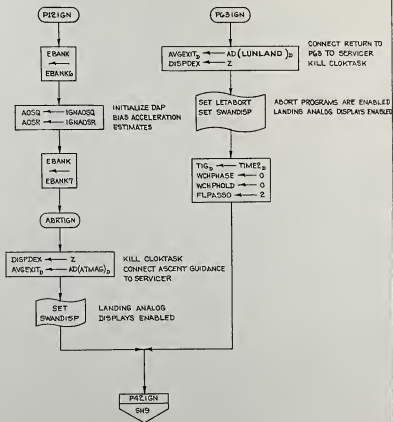




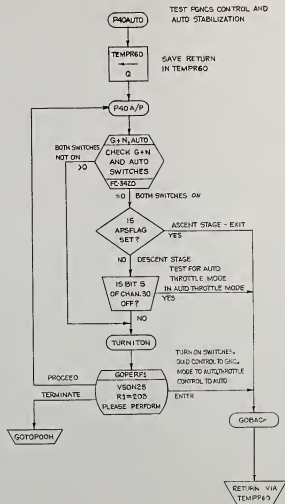
|   |  |   |  |
|---|--|---|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.  |  | APPLIC<br>GUIDANCE AND NAVIGATION   |  |
| DESIGNED BY: A. C. WILLIAMS<br>DRAWN BY: C. Schultenberg<br>ANALYST: [Signature]<br>CHECKED BY: [Signature]<br>APPROVED BY: [Signature] |  | BURN BABY BURN<br>(MASTER IGNITION ROUTINE)<br>LUMINARY IC<br>DOCUMENT # FC-3840<br>REV 2 |  |



| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |               | APOLLO<br>GUIDANCE AND NAVIGATION |               |
|--|---------------|-----------------------------------|---------------|
| BURN BABY BURN<br>(MASTER IGNITION ROUTINE)    |               | DOCUMENT #                        |               |
| DESIGNER A.C. WILLIAMS                         | DATE 10/10/69 | LUMINARY 1C                       | FC-3840       |
| PREPARED C. Schubert                           | DATE 11/11/69 | REV 2                             | SHEET 9 OF 25 |
| ANALYST  |               |                                   |               |
| DESIGNED BY                                    |               |                                   |               |
| APPROVED                                       |               |                                   |               |



|  |      |                                |   |
|--|------|--------------------------------|---|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |      | ARTICLE<br>DESIGN AND VALIDATE |   |
| DRAWN A.C. WILLIAMS                            |      | DATE                           | BURN BABY BURN<br>(MASTER IGNITION ROUTINE) |
| DESIGN C. Schulenberg                          | DATE | LUMINARY IC                    | DOCUMENT NO. FC-384                         |
| ANALYST M.C. Engstrom                          | DATE | REV 2                          | SHEET 10 OF 15                              |
| APPROVED J. S. S. S. S.                        | DATE |                                |   |



A.C. WILLIAMS

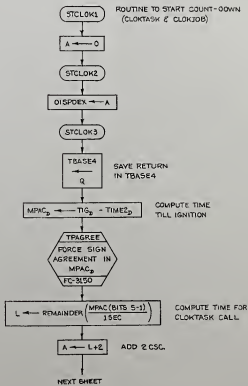
G-2548

BURN BABY BURN  
(MASTER IGNITION ROYALTY)

LUMINARY 1C

FC-3847

11 25



A.C.WILLIAMS

6-27-68

BURN BABY BURN  
(MASTER IGNITION ROUTINE)

LUMINARY IC

FC-3840

2

10

25

*P. Collier*

7-20-68

*P. Collier*

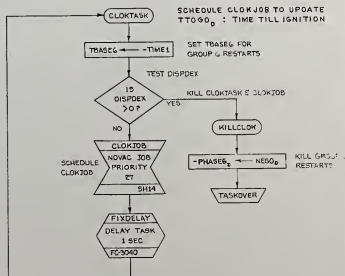
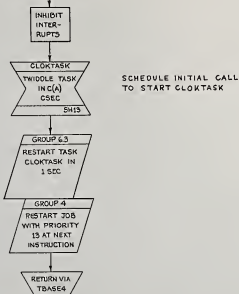
11-2-68

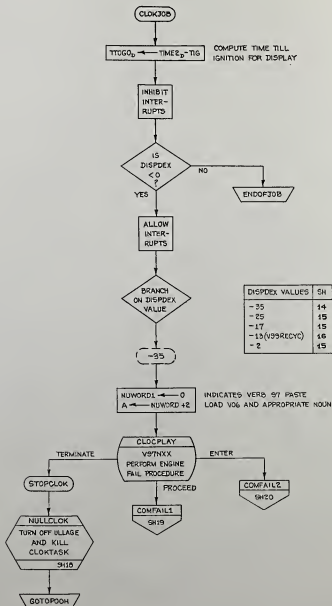
*W. C. Collier*

9-29-68

*John A. Brown*

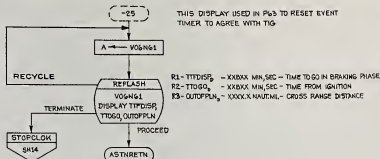
2-10-69





|  |         |   |                |
|--|---------|---|----------------|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |         | APOLLO<br>C-14 AND NAVIC-10                 |                |
| DRAWN <u>A.C. WILLIAMS</u>                     |         | BURN BABY BURN<br>(MASTER IGNITION ROUTINE) |                |
| PROF. <u>C. Schulenberg</u>                    | 6/11/69 | LUMINARY 1C                                 | DOCUMENT #     |
| ANALYST <u>W. J. J. J.</u>                     | 6/11/69 |   | FC-3840        |
| APPROV. <u>W. J. J. J.</u>                     | 6/11/69 | REV 2                                       | SHEET 14 OF 25 |



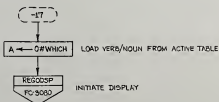


GROUP 4  
SET UP RESTARTS  
TO RESTART JOB  
AT NEXT LOCATION  
WITH SAME PRIORITY

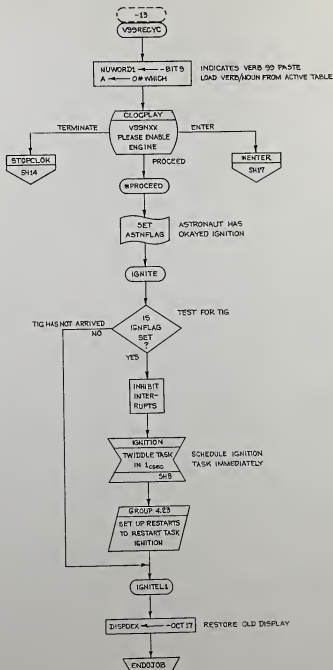
DISPDEX ← 0 STOP DISPLAY

ASTNRET  
FINDVAC JOB  
PRIORITY  
13 SCHEDULE JOB 10  
RETURN TO P63 ROUTINE  
FC-3900  
ENDOFJOB

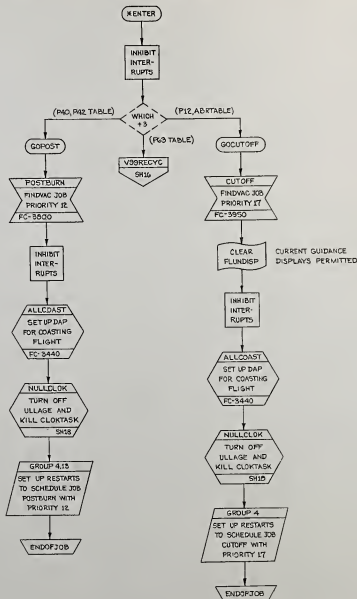
| WHICH<br>TABLE | VERB/<br>NOUN |
|----------------|---------------|
| P12            | 06 74         |
| P40            | 06 40         |
| P42            | 06 40         |
| P63            | 06 62         |
| ABRTABLE       | 06 63         |



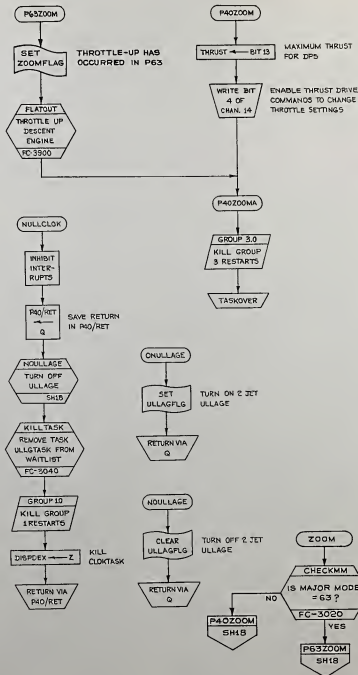
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|--|------------------|---|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                  | APPROU<br>C. "ANY" ANY QUALIFICATION        |  |
| DESIGNED BY<br>A.C. WILLIAMS                   | DATE<br>11/20/65 | BURN BABY BURN<br>(MASTER IGNITION ROUTINE) |  |
| DESIGNED BY<br>C. Schulerberg                  | DATE<br>6/20/67  | LUMINARY IC                                 |  |
| DESIGNED BY<br>J. P. D. Smith                  | DATE<br>1/16/69  | FC-384)                                     |  |
| APPROVED BY<br>C. Schulerberg                  | DATE<br>6/20/67  | REV 2                                       |  |



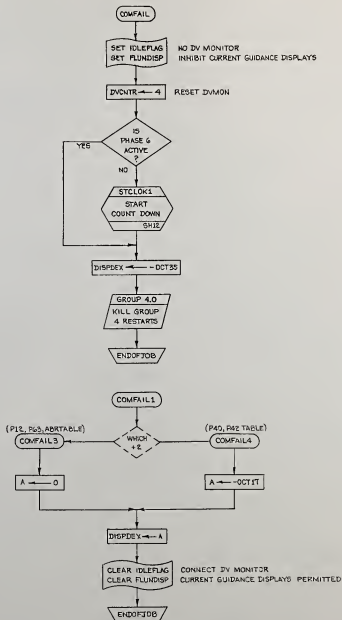
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|--|-------------------------------|---|--------------|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                               | APPLIC<br>CUMMANT AND NAVIGATION            |              |
| DESIGNED BY<br>A.C. WILLIAMS                   | DESIGNED BY<br>C. Schulerberg | BURN BABY BURN<br>(MASTER IGNITION ROUTINE) |              |
| ANALYST<br>J.C. Bognet                         | ANALYST<br>J.C. Bognet        | LUMINARY NO.                                | DOCUMENT NO. |
| REVIEWED BY<br>J.C. Bognet                     | REVIEWED BY<br>J.C. Bognet    | FC-3840                                     | REV 2        |



|  |  |   |  |
|--|--|---|--|
| MIT<br>INSTRUMENTATION LAB<br>WATERTOWN, MASS.   |  | 7-11-63<br>OF 7-11-63 AND 7-11-63   |  |
| DRAWN BY: A. C. WILLIAMS<br>CHECKED BY: G. Schulerberg<br>ANALYST: J. C. Schulerberg<br>DESIGNED BY: J. C. Schulerberg<br>APPROVED BY: J. C. Schulerberg |  | BURN BABY BURN<br>(MASTER IGNITION ROUTINE)<br>LUMINARY 1C<br>FC-3840<br>REV. 1 |  |



|  |          |                                   |                |
|--|----------|-----------------------------------|----------------|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |          | APOLLO<br>GUIDANCE AND NAVIGATION |                |
| BURN BABY BURN<br>(MASTER IGNITION ROUTINE)    |          |                                   |                |
| DRAWN A.C. WILLIAMS                            | DESIGNED | LUMINARY 1C                       | DOCUMENT NO.   |
| FIGURE 3. Schulerberg                          | 6. 1965  |                                   | FC-3840        |
| ANALYST  |          |                                   |                |
| DESIGNED BY                                    | 6. 1965  |                                   |                |
| APPROVED                                       | REV 2    |                                   | SHEET 15 OF 18 |



MIT  
INSTRUMENTATION LAB  
CAMBRIDGE, MASS.

DESIGNED BY A.C. WILLIAMS  
DRAWN BY G. SCHULBERG  
CHECKED BY J. D. BARNETT  
APPROVED BY J. D. BARNETT

APOLLO  
GUIDANCE AND NAVIGATION

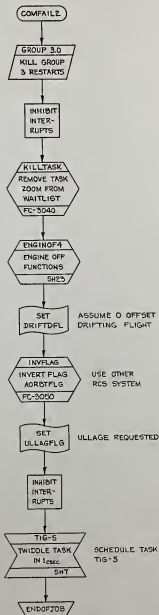
BURN BABY BURN  
(MASTER IGNITION ROUTINE)

ILLUMINARY IC

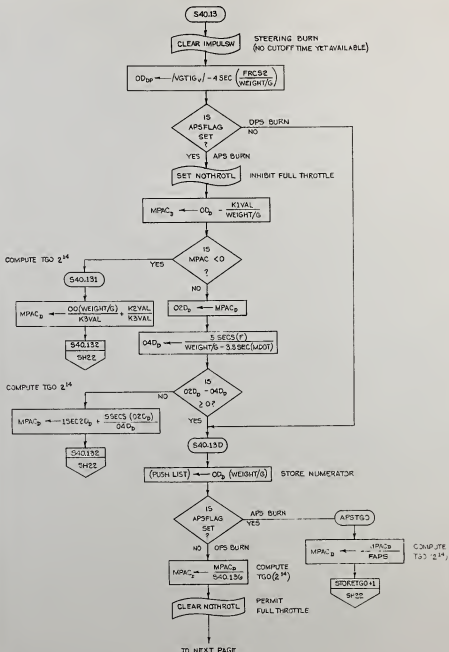
DOCUMENT NO.  
FC-3840

REV 2

SEP 1968



|  |  |  |  |
|--|--|--|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.   |  | APOLLO<br>CE-200C AND NAVIGANT   |  |
| DESIGNER <u>A.C. WILLIAMS</u> 137060<br>DRAWN <u>C. Schulberg</u> 6466<br>ANALYST <u>[Signature]</u> 6466<br>CHECKED <u>[Signature]</u> 6466<br>APPROVED <u>[Signature]</u> 6466 |  | BURN BABY BURN<br>(MASTER IGNITION ROUTINE)<br>LUMINARY IC<br>FC-384<br>SHEET 20 OF 25 |  |



ACWILLIAMS 6-28-60  
B. Allen 6-28-60  
J. G. Bennett 7-29-60  
John T. Brown 8-16-60

BURN BABY BURN  
(MASTER IGNITION ROUTINE)

LUMINARY 1C

FC-3840

21 15



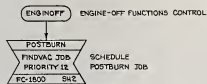




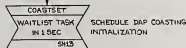
TASKOVER



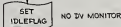
TASKOVER



ENGINEOF2



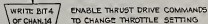
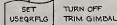
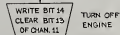
ENGINEOF1



ENGINEOF4

TEVEN<sub>6</sub> ← TIME2<sub>3</sub>

ENGINEOF3



RETURN VIA  
ISWRETRN

|  |  |   |  |
|--|--|---|--|
| MIL<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.   |  | APOLLO<br>G.C. SANEY AND NAVIGATION                                 |  |
| DESIGNED BY: A.C. WILLIAMS<br>DRAWN BY: C. Schusterberg<br>CHECKED BY: [Signature]<br>APPROVED BY: [Signature] |  | BURN BABY BURN<br>(MASTER IGNITION ROUTINE)<br>LUMINARY 1C<br>REV 2 |  |
| DATE: 11/1/68<br>BY: [Signature]   |  | FC-3840<br>SHEET 24 OF 25   |  |

SUBROUTINES CALLED WHICH ARE  
FLOWED ON OTHER FLOW CHARTS

| SUBROUTINE NAME | FLOW CHART | DESCRIPTION                               | WHERE CALLED |
|-----------------|------------|---|--------------|
| ALLCOAST        | FC-3440    | SET UP OAP FOR COASTING FLIGHT            | SH. 17, 23   |
| CHECKMM         | FC-3020    | TEST MAJOR MODE                           | SH. 4, 8     |
| CLEANDSP        | FC-3080    | BLANK DSKY                                | SH. 5, 15    |
| CSMPREC         | FC-3350    | EXTRAPOLATE CSM STATE VECTOR              | SH. 3        |
| FIXDELAY        | FC-3040    | DELAY ACTIVE TASK                         | SH. 0, 13    |
| FLATOUT         | FC-3900    | THROTTLE UP DESCENT ENGINE                | SH. 18       |
| G&N, AUTO       | FC-3420    | CHECK G&N AND AUTO SWITCHES               | SH. 11       |
| INVFLAG         | FC-3050    | INVERT INPUT FLAG BIT                     | SH. 20       |
| KILLTASK        | FC-3040    | REMOVE TASK FROM WAITLIST                 | SH. 18, 20   |
| MIDTOAVI        | FC-3350    | INTEGRATE LM STATE VECTOR                 | SH. 3        |
| MUNGRAV         | FC-3850    | COMPUTE LUNAR GRAVITATIONAL ACCELERATION  | SH. 3        |
| TPAGREE         | FC-3150    | FORCE SIGN AGREEMENT IN MPAC <sub>T</sub> | SH. 12, 22   |

FLAGS

| NAME                       | MEANING WHEN SET                    | MEANING WHEN CLEAR                  | WHERE SET  | WHERE CLEARED | WHERE TESTED |
|----------------------------|-------------------------------------|-------------------------------------|------------|---------------|--------------|
| APSFFLAG<br>FL. 10, BIT13  | ASCENT STAGE                        | DESCENT STAGE                       |            |               | SH. 11       |
| ASTNFLAG<br>FL. 7, BIT12   | ASTRONAUT HAS OKAYED IGNITION       | ASTRONAUT HAS NOT OKAYED IGNITION   | SH. 5, 16  | SH. 7, 9      | SH. 8        |
| DRIFTDFL<br>FL. 13, BIT8   | T3RUPT CALLS GYRO COMPENSATION      | T3RUPT DOES NO GYRO COMPENSATION    | SH. 20     | SH. 8         |              |
| ENGONFLG<br>FL. 5, BIT7    | ENGINE TURNED ON                    | ENGINE TURNED OFF                   | SH. 8      | SH. 23        |              |
| FLUNDISP<br>FL. 6, BIT10   | CURRENT GUIDANCE DISPLAYS INHIBITED | CURRENT GUIDANCE DISPLAYS PERMITTED | SH. 19     | SH. 9, 17, 19 |              |
| IDLEFLAG<br>FL. 7, BIT7    | NO DV MONITOR                       | CONNECT DV MONITOR                  | SH. 19     | SH. 9, 19     |              |
| IGNFLAG<br>FL. 7, BIT13    | TIG HAS ARRIVED                     | TIG HAS NOT ARRIVED                 | SH. 8      | SH. 7, 9      | SH. 16       |
| IMPULSW<br>FL. 2, BIT9     | MINIMUM IMPULSE BURN                | STEERING BURN                       | SH. 22     | SH. 9, 21     | SH. 9        |
| MUNFLAG<br>FL. 9, BIT8     | SERVICER CALLS MUNRVG               | SERVICER CALLS CALCRVG              |            |               | SH. 3        |
| NOTHROTL<br>FL. 5, BIT12   | INHIBIT FULL THROTTLE               | PERMIT FULL THROTTLE                | SH. 21, 22 | SH. 21        | SH. 9        |
| ULLAGFLG<br>FL. 13, BIT6   | ULLAGE REQUESTED BY MISSION PROGRAM | NO INTERNAL ULLAGE REQUEST          | SH. 18, 20 | SH. 18        |              |
| USEQONFLG<br>FL. 13, BIT14 | GIMBAL UNUSABLE. USE JETS ONLY      | TRIM GIMBAL MAY BE USED             | SH. 23     |               |              |
| LETAORT<br>FL. 9, BIT9     | ABORT PROGRAMS ARE ENABLED          | ABORT PROGRAMS ARE NOT ENABLED      | SH. 10     |               |              |
| PULSEFLG<br>FL. 13, BIT15  | MINIMUM IMPULSE COMMAND MODE        | NOT IN MINIMUM IMPULSE COMMAND MODE |            | SH. 10        |              |
| SWANDISP<br>FL. 7, BIT11   | LANDING ANALOG DISPLAYS ENABLED     | LANDING ANALOG DISPLAYS SUPPRESSED  | SH. 10     |               |              |

|  |                     |   |  |
|--|---------------------|---|--|
| WIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                     | APOLLO<br>GUIDANCE AND NAVIGATION           |  |
| DRAWN BY <i>J. Schumaker</i>                   |                     | BURN BABY BURN<br>(MASTER IGNITION ROUTINE) |  |
| CHECKED BY <i>J. Schumaker</i>                 | DATE <i>6/20/69</i> | LUMINARY IC                                 |  |
| APPROVED BY <i>J. Schumaker</i>                | DATE <i>6/24/69</i> | SHEET 24 OF 25                              |  |

# DISPLAYS

|                  |  |        |
|------------------|--|--------|
| V06N40<br>V99N40 | R1 - TTOGO - XXBXX MIN-SEC - TIME TO IGNITION/CUTOFF<br>R2 - VGDISP - XXXX.X FT/SEC-VG<br>R3 - DVTOTAL - XXXX.X FT/SEC - DELTA V | SH. 13 |
|------------------|--|--------|

# ERASABLE LOCATIONS USED

|                  |                                 | UNITS | SCALING         |
|------------------|---------------------------------|-------|-----------------|
| TIG <sub>D</sub> | TIME OF ENGINE IGNITION         | CSEC  | 2 <sup>28</sup> |
| TGO <sub>D</sub> | TIME FROM ENGINE CUT-OFF        | CSEC  | 2 <sup>28</sup> |
| PIF<br>THRUST    | AUTO THROTTLE COMMAND REGISTERS | -     | -               |

|  |  |   |  |
|--|--|---|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APPRO: GUIDANCE AND NAVIGATION              |  |
| DEARN <i>A. P. New</i> STUDYED                 |  | BURN BABY BURN<br>(MASTER IGNITION ROUTINE) |  |
| FRESH <i>C. Schulerberg</i> 1/10/61            |  | LUMINARY IC                                 |  |
| ANALYST <i>W. B. B. B. B.</i> 1/10/61          |  | DOCUMENT NO. FC-3840                        |  |
| DOCTR <i>W. B. B. B. B.</i> 1/10/61            |  | SHEET 25 OF 25                              |  |
| APPRO <i>W. B. B. B. B.</i> 1/10/61            |  |   |  |

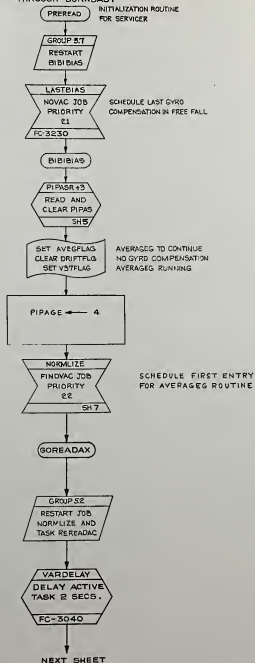
# SERVICER

## MAJOR SUBROUTINES ON THIS CHART

|                    |        |
|--------------------|--------|
| PREREAD            | Sh. 2  |
| PIPASR, PIPASR + 3 | Sh. 5  |
| SERVICER           | Sh. 8  |
| CALCRVG            | Sh. 17 |
| CALCGRV            | Sh. 17 |
| COPYCYC            | Sh. 18 |

|   |  |                                |                         |
|---|--|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.   |  | APOLLO GUIDANCE AND NAVIGATION |                         |
| SERVICER                                      |  |                                |                         |
| DRAWN<br><i>J. DeLorenzo</i><br>9/12/67       | PROGRAM<br><i>Richard M. Long</i><br>9/16/67 | LUMINARY<br>1C                 | DOCUMENT NO.<br>PC-3850 |
| ANALYST<br><i>McBride</i><br>9/16/67          | DOCTOR<br><i>McBride</i><br>9/16/67          | REV 2                          |                         |
| APPROVED<br><i>Richard M. Long</i><br>9/16/67 |  | SHEET 1 OF 10                  |                         |

CALL BY P12, P40, P41, P42, P47, AND P63  
THROUGH BURNBABY



SERVICER

A.C.WILLIAMS

6-11-68

... P. A. Williams  
... P. A. Williams  
... P. A. Williams  
... P. A. Williams

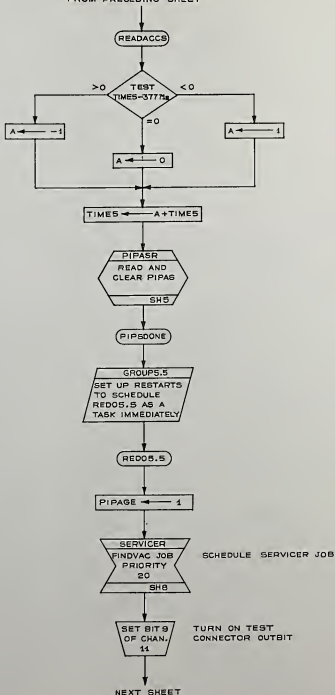
2/18/69 LUMINARY 10

FC-3850

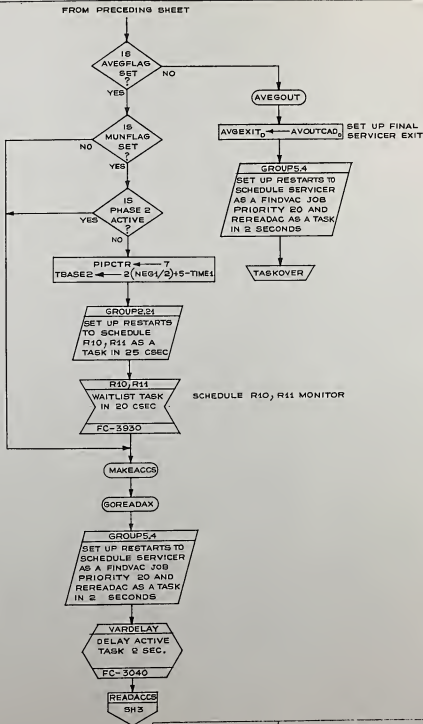
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2 20

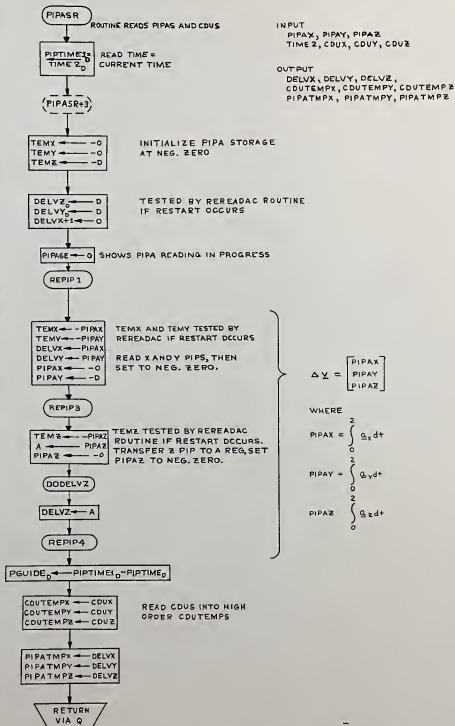
FROM PRECEDING SHEET



|  |  |  |  |
|--|--|--|--|
| MIT<br>INSTRUMENTATION DIV 4<br>FAC 80/350 MAPS  |  | ARCHIVE<br>AS 100 CAL A                  |  |
| DRAWN <i>P. M. Dietz</i> <i>12/10/67</i><br>CHECKED <i>C. Schulerberg</i> <i>12/10/67</i><br>BY <i>100 Dietz</i> <i>12/10/67</i><br>DATE <i>12/10/67</i> |  | SERVICER<br>LUMINARY IC<br>FC-3850<br>20 |  |



|  |  |                         |  |
|--|--|-------------------------|--|
| MIT<br>INSTRUMENTATION: 43<br>CAMBRIDGE, MASS.   |  | APPROVED AND NAVIGATION |  |
| DRAWN: <i>[Signature]</i><br>CHECKED: <i>[Signature]</i><br>APPROVED: <i>[Signature]</i> |  | SERVICER                |  |
| LUMINARY IC  |  | DOCUMENT NO. FC-3850    |  |
| REV. 2   |  | REV. 4                  |  |



SERVICER

25 JUL 68

LUMINARY 1C

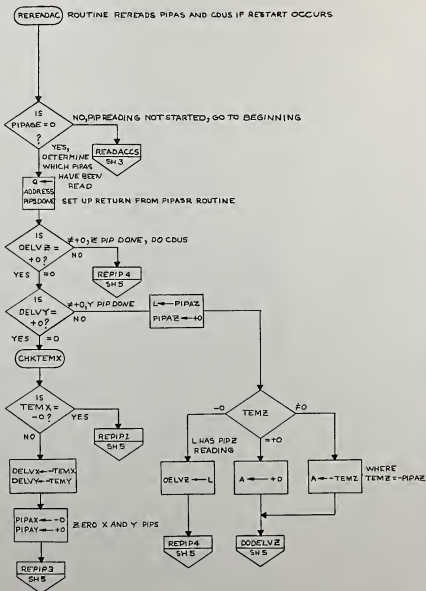
FC-3850

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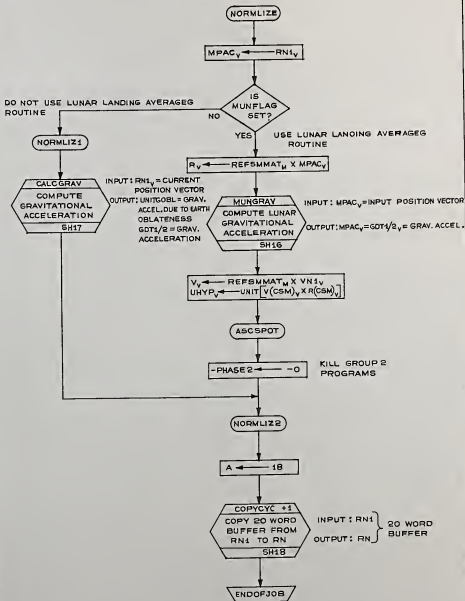


25 JUL 68  
7 AUG 68  
16 SEP 68  
27 JUL 68  
John G. New 29 JUL 68

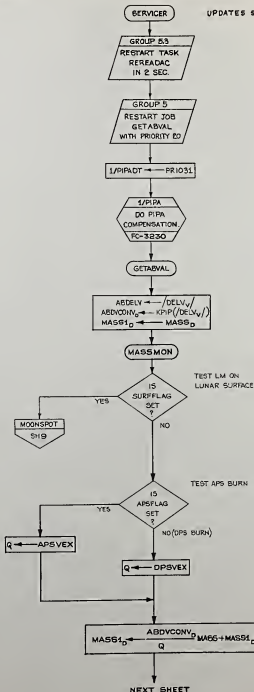
SERVICER

LUMINARY 1C

FC-3850



|   |  |
|---|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.  | APPROVED<br>GENERAL AND NAVIGATOR                                |
| DRAWN BY <i>[Signature]</i> 21 MAY 68<br>CHECKED BY <i>C. Schulerberg</i> 18 AUG 68<br>DESIGNED BY <i>[Signature]</i> 17 AUG 68<br>APPROVED BY <i>[Signature]</i> 17 AUG 68 | SERVICER<br>LUMINARY IC<br>DOCUMENT NO. FC-3850<br>SHEET 7 OF 20 |



SERVICER

LUMINARY 1C

FC-3850

8 20

A.C. WILLIAMS 6-12-60  
 B. Goff 8-7-68  
 J. A. Williams 10-16-69  
 J. A. Williams 1-24-66  
 J. A. Williams 2-11-67

FROM PRECEDING SHEET

MOONSPOT

$DVTOTAL_0 \leftarrow DVTOTAL_0 + KMP1(ABDELY_0)$

YMPDGP  
LOAD CDUS  
CORRESPONDING TO  
PIPTIME INTO  
CDUSPOT VECTOR  
SH14

QUICKTRIG  
COMPUTE  
SINES & COSINES  
OF CDU ANGLES  
FC=3320

INPUT: CDU VALUES IN CDUSPOT,  
OUTPUT: SINES & COSINES OF CDU ANGLES

A  
XNBPIPAD

LOAD A WITH ADDRESS OF  
BUFFER FOR FLESHPOT ROUTINE

FLESHPDT

SUBROUTINE TO FORM  
XNBPIR, YNBPIR, ZNBPIR

$XNBPIR_0 \leftarrow \begin{cases} \cos CDUY \cos CDUZ, \\ \sin CDUZ, \\ - \sin CDUY \cos CDUZ \end{cases}$

$ZNBPIR_0 \leftarrow \begin{cases} \cos CDUY \sin CDUZ \sin CDUZ + \cos CDUX \sin CDUY, \\ - \sin CDUX \cos CDUZ, \\ \cos CDUX \cos CDUY - \sin CDUX \sin CDUY \sin CDUZ \end{cases}$

$YNBPIR_0 \leftarrow (ZNBPIR_0) \times (XNBPIR_0)$

RETURN VIA  
SWRETURN

NEXT SHEET

SERVICE

A.C. WILLIAMS

6-14-68

*B. Carroll*

8-7-68

*J. A. Brown*

10-2-69

*John A. Brown*

24 MAR 69

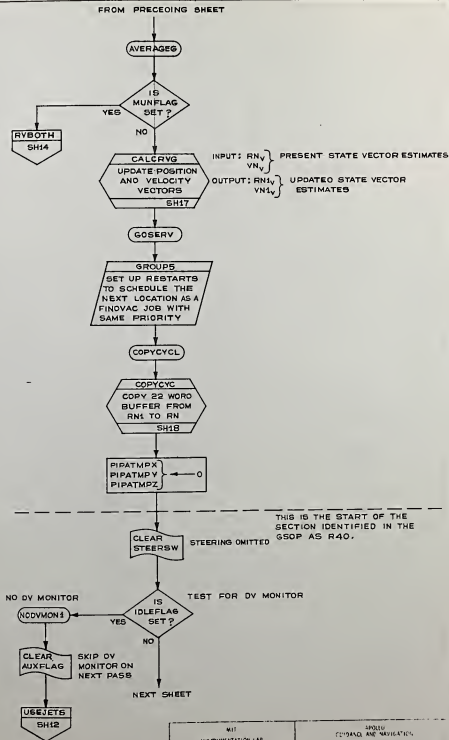
LUMINARY IC

FC-3850

2

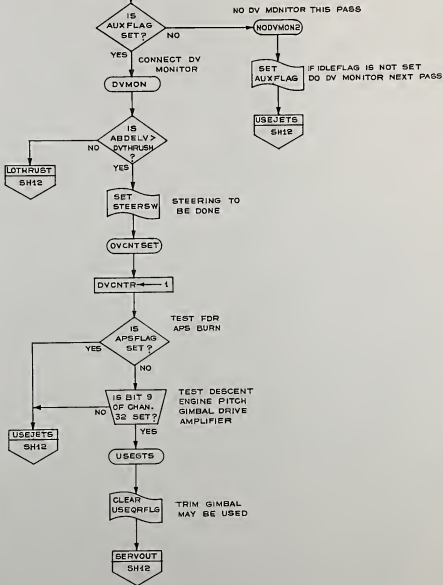
9

20

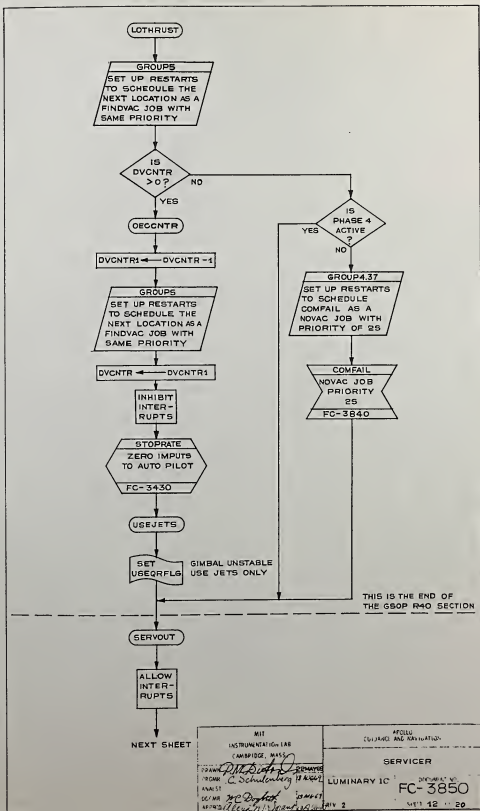


|  |  |  |  |
|--|--|--|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.   |  | SPOLLO<br>GUIDANCE AND NAVIGATION                      |  |
| DESIGNER: <i>P. H. Schulerberg</i><br>PROGRAMMER: <i>P. H. Schulerberg</i><br>ANALYST: <i>P. H. Schulerberg</i><br>CHECKER: <i>P. H. Schulerberg</i><br>APPROVED: <i>P. H. Schulerberg</i> |  | SERVICER<br><br>LUMINARY 10<br>FC-3850<br>Sept 10 1962 |  |
| DATE: <i>12 MAY 62</i><br>REV: <i>2</i>  |  |  |  |

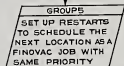
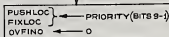
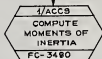
FROM PRECEDING SHEET



|  |  |                                   |  |
|--|--|-----------------------------------|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO<br>GUIDANCE AND NAVIGATION |  |
| DRAWN: <i>[Signature]</i>                      |  | SERVICER                          |  |
| FROM: <i>C. Schulenberg</i>                    |  | LUMINARY 1C                       |  |
| ANALYST: <i>MC Roshel</i>                      |  | DOCUMENT NO. FC-3850              |  |
| DRAWN: <i>MC Roshel</i>                        |  | REV. 2                            |  |
| APPROVED: <i>[Signature]</i>                   |  | PAGE 11 OF 20                     |  |



FROM PRECEDING SHEET



GO TO ROUTINE SPECIFIED  
IN AVGEXIT

AVGENO FC-3850  
CALCNB3 FC-3830  
CALCNB5 FC-3810  
SERVEXIT FC-3850  
STEERING FC-3820  
LUNLAND FC-3940  
ATMAG FC-3980  
P63DISP-2 FC-3900



(AVGEXIT = AVEGEXIT)

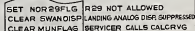
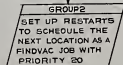
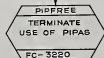
FINAL AVERAGES EXIT  
(END OF POWERED  
FLIGHT SET UP  
FOR FREE FALL)



SET UP FREE FALL  
GYRO COMPENSATION



T3RUP CALLS GYRO  
COMPENSATION



PERFORM TRANSITION FROM  
THRUSTING PHASE TO  
COASTING PHASE



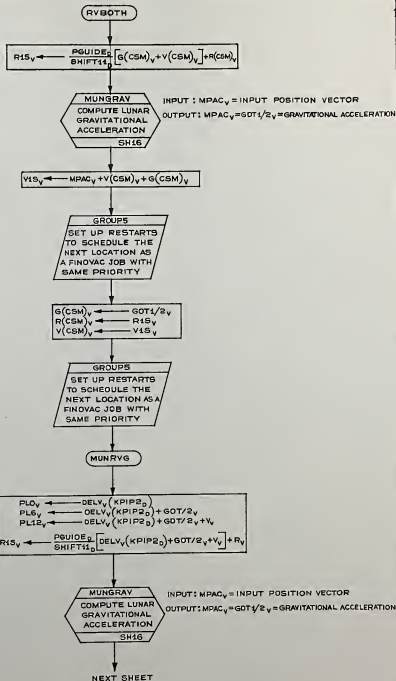
AVERAGES(SERVICER) OFF



DATE  
IMPLEMENTATION  
"AMBRIDGE" MASS  
LUMINARY IC  
FC-3850  
13 20

SERVICER  
LUMINARY IC  
FC-3850  
13 20





|                             |                        |
|-----------------------------|------------------------|
| MIT                         | APPROVED               |
| INSTRUMENTATION LAB         | EXTEND AND REE. LAB/CM |
| ANALYST: <i>[Signature]</i> | SERVICES               |
| DATE: <i>10/1/68</i>        | LUMINARY IC            |
| PROJECT: <i>FC-3850</i>     | FC-3850                |
| REVISION: <i>1</i>          | 14 21 20               |

FROM PRECEDING SHEET

$V1S_V \leftarrow MPAC_V + PL6_V + PLO_V + V_V$   
 $ABVEL_D \leftarrow V1S_V /$   
 $HDOTDISP_D \leftarrow UNIT/R_V \cdot V1S_V$   
 $DELVB_V \leftarrow (R1S_V \times WM_V) \times 4$   
 $HCALC_D \leftarrow R1S_V / -LAND_D$

MUNRETRN  
 R12 - DESCENT  
 STATE VECTOR  
 UPDATE  
 FC-3935

CDPYCYC1

GROUPE  
 SET UP RESTARTS  
 TO SCHEDULE THE  
 NEXT LOCATION AS A  
 FINDVAC JOB WITH  
 SAME PRIORITY

R29?

IS  
 NOR29FLG  
 OR READRFLG  
 SET?  
 YES NO

IS  
 RCDOUFLG  
 OR AUTOMODE  
 SET?  
 YES NO

IS  
 REMODFLG  
 OR REPOSOMN  
 SET?  
 YES NO

R29  
 POWERED FLIGHT  
 RR DESIGNATE  
 FC-3980

NOR29NOW

NEXT SHEET

R29NODES

INHIBIT  
 INTER-  
 RUPTS

RR DESIGNATE  
 NOT REQUESTED  
 OR IN PROGRESS

CLEAR  
DESIGFLG

MIT  
 INSTRUMENTATION LAB  
 CAMBRIDGE MASS

KRELL  
 (U-DAV) AND VAV...

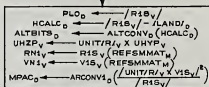
SERVICER

LUMINARY 10

FC-3850

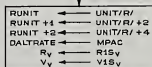
15 11 80

FROM PRECEDING SHEET



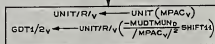
COPYCYC2

INHIBIT  
INTER-  
RUPTS



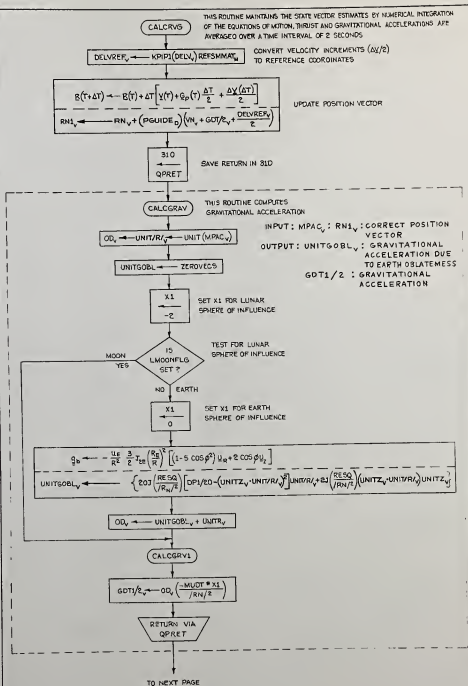
COPYCYCL  
SH10

MUNGRAV



RETURN VIA  
QPRET

|   |  |
|---|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.  | APOLLO<br>CLIMBANCE AND NAVIGATION                   |
| DRAWN <i>D.M. Smith</i><br>CHECKED <i>C. Schultzeberg</i><br>KNOWN<br>DATE <i>10/1/68</i><br>APPROVED <i>Reginald</i> | SERVICER<br>LUMINARY 10<br>FC-3850<br>SHEET 16 OF 20 |



SERVICER

A.C. WILLIAMS 6-15-68

B. Powell 8-7-68

J. Sullivan 10-2-69

J. Sullivan 6-24-68

J. Sullivan 2-24-69

LUMINARY IC

FC-3850

17 20

FROM PRECEDING PAGE

$$\begin{aligned} Y(T+\Delta T) &\leftarrow Y(T) + \frac{\Delta T}{2} \left[ g(T+\Delta T) + g_0(T) \right] + \Delta Y(\Delta T) \\ VN1_v &\leftarrow VN_v + GUT1/2_v + GUT2_v + DELVREF_v \end{aligned}$$

UPDATE VELOCITY VECTOR

RETURN VIA  
31D

TMPTOSPT

SUBROUTINE TO LOAD CDUS CORRESPONDING  
TO PIPTIME INTO CDUSPT VECTOR

CDUSPTY  $\leftarrow$  CDUTEMPY  
CDUSPTZ  $\leftarrow$  CDUTEMPZ  
CDUSPTX  $\leftarrow$  CDUTEMPX

RETURN VIA  
DANZIG

COPYCYC

SUBROUTINE TO COPY 22 WORD BUFFER  
FROM RN1 TO RN

A  $\leftarrow$  20

COPYCYC + 1

INHIBIT  
INTER-  
RUPTS

COPYCYC + 21

ITEMP1  $\leftarrow$  A(BITS 15-2)

MAKE ITEMP1 AN  
EVEN NUMBER

DECREMENT  
ITEMP1

ITEMP1  $\leftarrow$  ITEMP1-1

RN0 # ITEMP1  $\leftarrow$  RN10 # ITEMP1

IS  
ITEMP1 = 0  
?

RETURN  
VIA Q

A C WILLIAMS

6-15-68

SERVICER

B. C. Smith

8-7-68

LUMINARY IC

FC-3850

11-6-68

6-24-68

2

18 20

SUBROUTINES CALLED WHICH ARE  
FLOWED ON OTHER FLOW CHARTS

| SUBROUTINE<br>NAME | FLOW<br>CHART | DESCRIPTION   | WHERE<br>CALLED |
|--------------------|---------------|---|-----------------|
| AVETOMID           | FC-3350       | INITIALIZE PERMANENT STATE VECTOR FOR<br>COASTING PHASE | SH. 13          |
| COMFAIL            | FC-3840       | THRUST FAIL PROGRAM                                     | SH. 12          |
| LASTBLAS           | FC-3230       | LAST GYRO COMPENSATION IN FREE FALL                     | SH. 2           |
| PIPFREE            | FC-3220       | TERMINATE USE OF PIPAS                                  | SH. 13          |
| QUICTRIG           | FC-3320       | COMPUTE SINES AND COSINES OF CDU ANGLES                 | SH. 9           |
| R10,R11            | FC-3930       | LANDING RADAR MONITOR                                   | SH. 4           |
| R20                | FC-3980       | POWERED FLIGHT RR DESIGNATE                             | SH. 15          |
| STOPRATE           | FC-3430       | ZERO INPUTS TO AUTOPILOT                                | SH. 12          |
| VARDELAY           | FC-3040       | DELAY ACTIVE TASK                                       | SH. 2, 4        |
| 1/ACCS             | FC-3490       | COMPUTE MOMENTS OF INERTIA                              | SH. 13          |
| 1/PIPA             | FC-3230       | COMPENSATE PIPAS AND GYROS                              | SH. 8           |

ERASABLE LOCATIONS USED

| AGC<br>TAG           | GSOP<br>SYMBOL | MEANING   | ENGINEERING<br>UNITS | AGC<br>UNITS | AGC<br>SCALING   |
|----------------------|----------------|---|----------------------|--------------|------------------|
| DVTOTAL <sub>D</sub> |                | ACCUMULATED DELTA-V   | FEET/SEC             | M CSEC       | 2 <sup>-7</sup>  |
| GDTI-2 <sub>V</sub>  |                | GRAVITATIONAL ACCELERATION<br>VECTOR (DELTA TIME)                                   | FEET/SEC             | M CSEC       | 2 <sup>-7</sup>  |
| MASS <sub>1D</sub>   |                | VEHICLE MASS  | POUNDS               | KG           | 2 <sup>-16</sup> |
| POUIDE <sub>D</sub>  |                | DELTA PIP TIME  | SECONDS              | CSEC         | 2 <sup>28</sup>  |
| RN1 <sub>V</sub>     |                | LM POSITION VECTOR  | FEET                 | METERS       | 2 <sup>-20</sup> |
| VN1 <sub>V</sub>     |                | LM VELOCITY VECTOR  | FEET/SEC             | M/CSEC       | 2 <sup>-7</sup>  |
| XNBPIP <sub>V</sub>  | }              | STABLE MEMBER TO<br>NAVIGATION BASE TRANSFORM-<br>ATION MATRIX FOR LAST<br>PIP TIME | -                    | -            | 2 <sup>-1</sup>  |
| YNBPIP <sub>V</sub>  |                |   | -                    | -            | 2 <sup>-1</sup>  |
| ZNBPIP <sub>V</sub>  |                |   | -                    | -            | 2 <sup>-1</sup>  |

|  |                            |                                   |                         |
|--|----------------------------|-----------------------------------|-------------------------|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                            | APOLLO<br>GUIDANCE AND NAVIGATION |                         |
| DRAWN <i>A. B. Neuf</i>                        |                            | SERVICER                          |                         |
| DESIGNED <i>A. B. Neuf</i>                     | ANALYST <i>A. B. Neuf</i>  | LUMINARY IC                       | DOCUMENT NO.<br>FC-3850 |
| DATE <i>12-14-67</i>                           | APPROVED <i>A. B. Neuf</i> | REV 2                             | SHEET 19 OF 20          |

FLAGS

| NAME                           | MEANING WHEN SET  | MEANING WHEN CLEAR                        | WHERE SET | WHERE CLEARED | WHERE TESTED |
|--------------------------------|---|---|-----------|---------------|--------------|
| APSFFLAG<br>FLAG 10<br>BIT 13  | APS BURN  | DPS BURN                                  |           |               | SH. 8, 11    |
| AUTOMODE<br>FLAG 12<br>BIT 2   | RR NOT IN AUTO MODE   | RR IN AUTO MODE                           |           |               | SH. 15       |
| AUXFLAG<br>FLAG 6<br>BIT 2     | IF IDLEFLAG IS NOT SET, SERVICER WILL DO DVMON ON NEXT PASS | SERVICER WILL SKIP DVMON ON NEXT PASS     | SH. 11    | SH. 10        | SH. 11       |
| AVERGFLAG<br>FLAG 7<br>BIT 5   | AVERAGE (SERVICER) DESIRED                                  | AVERAGE (SERVICER) NOT DESIRED            | SH. 2     |               | SH. 4        |
| DESIGFLAG<br>FLAG 14<br>BIT 10 | RR DESIGNATE REQUESTED OR IN PROGRESS                       | RR DESIGNATE NOT REQUESTED OR IN PROGRESS |           | SH. 15        |              |
| DRIFTFLAG<br>FLAG 2<br>BIT 15  | TSRUPT CALL GYRO COMPENSATION                               | TSRUPT DOES NOT GYRO COMPENSATION         | SH. 13    | SH. 2         |              |
| MUNFLAG<br>FLAG 6<br>BIT 8     | USE LUNAR LANDING AVERAGE                                   | DO NOT USE LUNAR LANDING AVERAGE          |           | SH. 13        | SH. 4, 7, 10 |
| NOI29FLAG<br>FLAG 3<br>BIT 11  | R29 NOT ALLOWED   | R29 ALLOWED                               | SH. 13    |               | SH. 15       |
| RCDU0FLAG<br>FLAG 12<br>BIT 13 | RR CDU'S BEING ZEROED                                       | RR CDU'S NOT BEING ZEROED                 |           |               | SH. 15       |
| READRFLAG<br>FLAG 3<br>BIT 8   | READING RR DATA PURSUANT TO R29                             | NOT READING RR DATA PURSUANT TO R29       |           |               | SH. 15       |
| REMODFLAG<br>FLAG 12<br>BIT 14 | CHANGE IN ANTENNA MODE BEEN REQUESTED                       | NO REMODE REQUEST OR OCCURRING            |           |               | SH. 15       |
| REPOSMON<br>FLAG 14<br>BIT 11  | RR REPOSITION IS TAKING PLACE                               | NO REPOSITION TAKING PLACE                |           |               | SH. 15       |
| STEERSW<br>FLAG 2<br>BIT 11    | STEERING TO BE DONE   | STEERING OMITTED                          | SH. 11    | SH. 10        |              |
| SURFFLAG<br>FLAG 8<br>BIT 8    | LM ON LUNAR SURFACE   | LM NOT ON LUNAR SURFACE                   |           |               | SH. 8        |
| SWANDISP<br>FLAG 7<br>BIT 11   | LANDING ANALOG DISPLAYS ENABLED                             | LANDING ANALOG DISPLAYS SUPPRESSED        |           | SH. 13        |              |
| USEQRFLAG<br>FLAG 13<br>BIT 14 | GIMBAL UNUSABLE. USE JETS ONLY                              | TRIM GIMBAL MAY BE USED                   | SH. 12    | SH. 11        |              |
| V37FLAG<br>FLAG 7<br>BIT 6     | AVERAGE (SERVICER) RUNNING                                  | AVERAGE (SERVICER) OFF                    | SH. 2     | SH. 13        |              |

|  |   |                                   |  |
|--|---|-----------------------------------|--|
| MIT<br>INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.   |   | APOLLO<br>GUIDANCE AND NAVIGATION |  |
| SERVICER   |   |                                   |  |
| DRAWN <i>W. D. [unclear]</i><br>CHECKED <i>L. Schubert</i><br>DESIGNED <i>[unclear]</i><br>APPROVED <i>[unclear]</i> | DATE <i>11/1/68</i><br>BY <i>[unclear]</i><br>LUMINARY IC 1<br>SHEET 20 OF 20 | DOCUMENT NO.<br><b>FC-3850</b>    |  |

# LUNAR LANDING

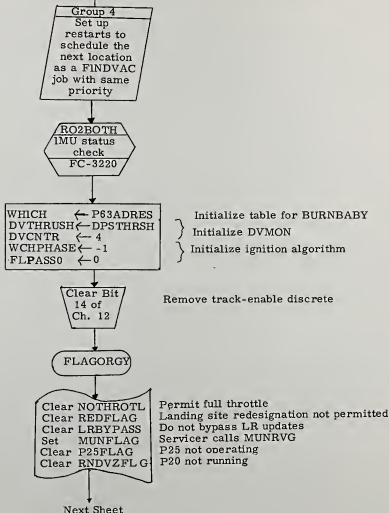
## MAJOR SUBROUTINES ON THIS CHART

|          |                                 |       |
|----------|---------------------------------|-------|
| P63LM    | LUNAR LANDING BRAKING PHASE     | SH 2  |
| GUILDRET | GUIDANCE ENTRY FROM R13 ROUTINE | SH 5  |
| P63DISPS | P63 DISPLAY ROUTINE ENTRY       | SH 27 |
| FLATOUT  | FULL THROTTLE ON DPS ENGINE     | SH 39 |

|   |     |                                |                         |
|---|-----|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |     | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN <i>[Signature]</i> 9/13/69            |     | Lunar Landing                  |                         |
| PRGMR <i>[Signature]</i> 8-25-69            |     | LUMINARY IC                    | DOCUMENT NO.<br>FC-3900 |
| ANALST                                      |     |                                |                         |
| DOCMR <i>[Signature]</i> 9/30/69            |     |                                |                         |
| APPR'D <i>[Signature]</i> 11/18/69          | REV | SHEET 1 OF 46                  |                         |



P63LM Lunar landing braking phase program



|   |                  |                                |                         |
|---|------------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                  | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN <i>A. H. H. H. H. H.</i>              |                  | Lunar Landing                  |                         |
| PRGMR                                       |                  | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3900 |
| ANALST                                      |                  |                                |                         |
| DOCNR                                       | <i>30-20-100</i> |                                |                         |
| APPR'D <i>R. L. L. L. L.</i>                | <i>4/5/68</i>    | REV                            | SHEET 2 OF 46           |

From Preceding Sheet

IGNALG

Set  
PUSHLIST  
to zero

$PL0_V \leftarrow RLS_V$   
 $PL6_D \leftarrow TLAND_D$   
 $TPIP_D \leftarrow TLAND_D$

Landing site vector

Estimated time of landing

RP-TO-R  
Transform from  
planetary to  
basic ref. system  
FC-3340

Inputs: MPAC  $\neq$  0 for moon

$PL0_V$  = RP vector

$PL6_D$  = Time

Output: MPAC<sub>V</sub> = R vector

$LAND_V \leftarrow REFSMMAT_M(MPAC_V)$

GUIDINIT  
Initialize  
 $WM_V$  and  
 $/LAND/ D$   
FC-3950

Outputs:  $WM_V$  = Lunar rotation vector

$/LAND/ D$  = Lunar radius at  
landing site

$TDEC1_D \leftarrow TLAND_D - GUIDDURN_D$

Initial estimate of full-thrust-  
position time

LEMPREC  
Integrate LM  
state vector to  
 $TDEC1_D$  time  
FC-3350

Inputs:  $TDEC1_D$ , LM state vector

Outputs:  $RATT_V$  = LM position vector

$VATT_V$  = LM velocity vector

$TAT_D$  = Time

NIGNLOOP( $\leftarrow PL40$ )  
 $CG_M \leftarrow \begin{cases} UNITX_V \\ UNITY_V \\ UNITZ_V \end{cases}$   
 $DELTAH_D \leftarrow 99999CON_D$   
 $UNFC/2_V \leftarrow 0$   
 $TTF18_D \leftarrow 0$

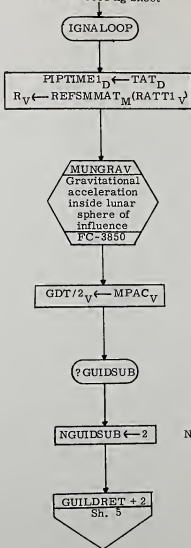
Initialize for V16N68 display

Initialize trim velocity correction term

Next Sheet

|   |                |                                |               |
|---|----------------|--------------------------------|---------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                | APOLLO GUIDANCE AND NAVIGATION |               |
| DRAWN <i>D. L. Sullivan 7/24/68</i>         |                | Lunar Landing                  |               |
| PRGMR                                       |                | LUMINARY .1C                   | DOCUMENT NO.  |
| ANALST                                      |                |                                | FC-3900       |
| DOCMR <i>W. D. Sullivan</i>                 | <i>7/30/68</i> | REV                            | SHEET 3 OF 46 |

From Preceding Sheet



Input:  $MPAC_V = R$  vector

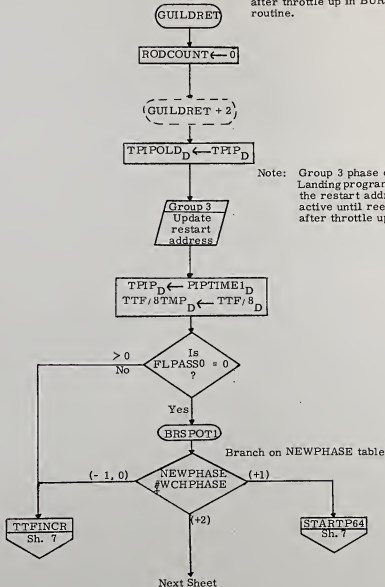
Output:  $MPAC_V = GDT1/2_V$

Delivers N passes of quadratic guidance

$N = 3$

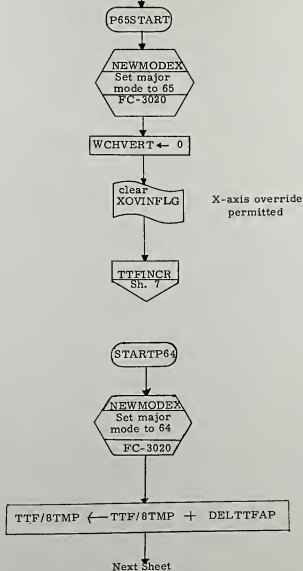
|   |                            |                                |                         |
|---|----------------------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                            | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN <i>S. Sullivan</i> 9/12/69            |                            | Lunar Landing                  |                         |
| PRGMR                                       |                            | ITERINARY /C                   | DOCUMENT NO.<br>FC-3800 |
| ANALST                                      |                            |                                |                         |
| DOCMR                                       | <i>W. D. Smith</i> 9/30/69 |                                |                         |
| APPR'D <i>R. Smith</i>                      | 10/16/69                   | REV                            | SHEET 4 OF 46           |

Entry to Guidance from R13 routine called by SERVICER every two seconds after throttle up in BURNBABY routine.



|   |  |                                |                         |
|---|--|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN _____                                 |  | Lunar Landing                  |                         |
| PRGMR _____                                 |  |                                |                         |
| ANALST _____                                |  |                                |                         |
| DOCMR <i>W. D. Smith</i> 7/30/67            |  | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3900 |
| APPR'D <i>R. S. Smith</i> 11/15/67          |  | REV _____                      | SHEET 5 of 46           |

From Preceding Sheet



|   |                          |                                |                         |
|---|--------------------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                          | APOLLO GUIDANCE AND NAVIGATION |                         |
|   |                          | Lunar Landing                  |                         |
| DRAWN                                       |                          | LUMINARY-1C                    | DOCUMENT NO.<br>FC-3000 |
| PRGMR                                       |                          |                                |                         |
| ANALST                                      |                          |                                |                         |
| DOCNR                                       | <i>20-10-10-10-10-10</i> | <i>7/20/69</i>                 |                         |
| APPR'D                                      | <i>10-10-10-10-10-10</i> | <i>11/5/69</i>                 | REV                     |
|   |                          |                                | SHEET 6 OF 46           |

From Preceding Sheet

Inhibit  
Inter-  
rupts

C13STALL  
Wait till  
ok to write  
Ch. 13  
FC-3340

Set bit  
12 of  
Ch. 13

Enable hand control rupt

DB ← P64DB

clear  
REDFLAG

Landing site redesignation  
not permitted

TTFINCR

$LANDTEMP_V \leftarrow /LAND/D \text{ unit} [LAND_V - LAND_V(TMP_D - TPIPOLD_D) \times WM_V]$

Landing site vector updated  
for lunar rotation

$TTF/8TMP_D \leftarrow TTF/8TMP_D + TMP_D - TPIPOLD_D$

Updated for time since last pass

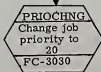
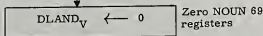
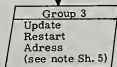
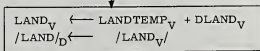
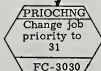
Group 3  
Update restart  
address  
(see note Sh. 5)

$TTF/8_D \leftarrow TTF/8TMP_D$

Next Sheet

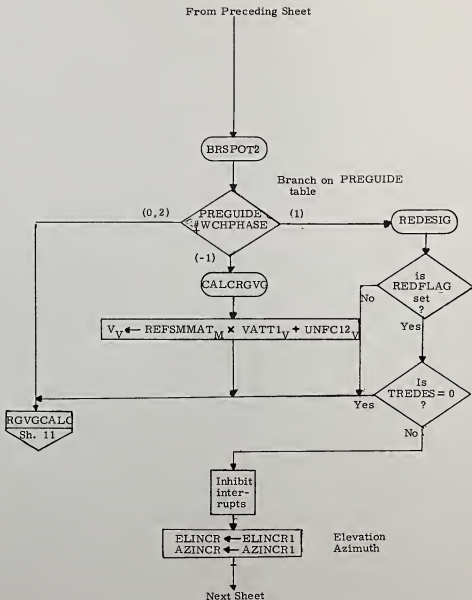
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| DRAWN                                       |                    | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3900 |
| PRGMR                                       |                    |                                |                         |
| ANALST                                      |                    |                                |                         |
| DOCMR                                       | <i>W. B. Smith</i> |                                |                         |
| APPR'D                                      | <i>W. B. Smith</i> | REV                            | SHEET 7 OF 46           |

From Preceding Sheet



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| DRAWN                                       |                    | LUMINARY 1C                    | DOCUMENT NO.  |
| PRGRM                                       |                    |                                | FC-3900       |
| ANALST                                      |                    |                                |               |
| DOCMR                                       | <i>W. H. H. H.</i> | 9/24/69                        |               |
| APPR'D                                      | <i>W. H. H. H.</i> | 11/15/69                       | REV           |
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| PRGMR _____                                 |  | LUMINARY IC                    |  |
| ANALST _____                                |  | DOCUMENT NO.<br>FC-3900        |  |
| DOCMR <i>W. D. Smith</i> 8/30/69            |  | REV _____                      |  |
| APPR'D <i>Robert M. Fisher</i> 11/18/69     |  | SHEET 9 of 46                  |  |



From Preceding Sheet

GROUP 3  
Update restart  
address  
(See note Sh. 5)

ELINCR 1 ← 0  
AZINCR 1 ← 0  
ELINCR +1 ← 0  
AZINCR +1 ← 0

Set  
PUSHLIST  
to zero

$PL0_V \leftarrow \text{Unit} \{ \text{LAND}_V - R_V \} + \text{AZINCR}_D \{ \text{YNBPIP}_V \}$  New landing  
-  $\text{ELINCR}_D \{ \text{Unit} \{ \text{LAND}_V - R_V \} \times \text{YNBPIP}_V \}$  site

Is  
 $PL0_D < -.02$

Test X component of vector

$PL0_D \leftarrow \text{DEPRCRIT}_D$

REDES1

$\text{LANDTEMP}_V \leftarrow | \text{LAND}_D | \left\{ \text{Unit} \left[ PL0_V \left( \frac{\text{LAND}_D - R_D}{PL0_D} \right) + R_V \right] \right\}$

GROUP 3  
Update restart  
address  
(See note Sh. 5)

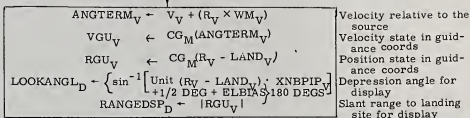
$\text{LAND}_V \leftarrow \text{LANDTEMP}_V$

Next Sheet

|   |  |                                |  |
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| ANALST _____                                |  | FC-3900                        |  |
| DOCMR <i>W. J. ...</i>                      |  | LUMINARY 1C                    |  |
| APPR'D <i>R. ...</i>                        |  | REV                            |  |
| 11/28/67                                    |  | SHEET 10 OF 46                 |  |

From Preceding Sheet

RGVGCALC



Set  
PUSHLIST  
to zero

BRSPOT3

Branch on WHATGUID table

WHATGUID  
#WCHPHASE

(2)

VERTGUID  
Sh. 30

(-1, 0, 1)

Next Sheet

|   |                    |                                |                |
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| PRGMR                                       |                    | DOCUMENT NO.                   |                |
| ANALST                                      |                    | LUMINARY IC                    | FC-3900        |
| DOCMR                                       | <i>X. Daylight</i> | 9/30/69                        |                |
| APPR'D RM E. E. E.                          | 11/15/69           | REV                            | SHEET 11 OF 46 |

From Preceding Sheet

TTF/8CL

INTPRETX

Load X1 with  
index for target  
parameters

Sh. 35

$TABLTTF \leftarrow 318DP_D (RDG + 4_D \cdot X1 - RGU + 4_D)$   
 $TABLTTF + 2_D \leftarrow VDG2TTF_D \cdot X1 + VGU \cdot 4_D \cdot 3/4DP_D$   
 $TABLTTF + 4_D \leftarrow ADG2TTF_D \cdot X1$   
 $TABLTTF + 6_D \leftarrow JDG2TTF_D \cdot X1$   
 $TABLTTF + 10 \leftarrow BIT \ 8$   
 $MPAC_D \leftarrow TTF/8_D$   
 $A \leftarrow TABLTTFL$   
 $L \leftarrow 2$

Load values for  
ROOTPSRS  
routine

ROOTPSRS

Double  
precision root  
finder  
Sh. 42

Output:  $MPAC_D =$   
 $TTFIB_D$

Good  
Return

(TTFIB is a nega-  
tive value)

$TTF18_D \leftarrow HPAC_D$

TDISPSET

Compute time  
remaining to  
redesignate  
Sh. 34

Next Sheet

Branch on WHATALM  
table

WHATALM  
#WCHPHASE

(-1)

(0, 1)

1406 POO

1406 ALM

ALARM

Store alarm  
code 1406  
FC-3140

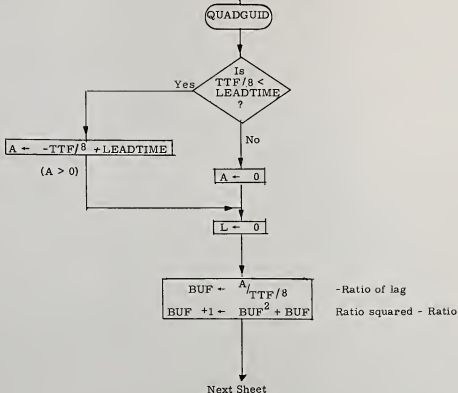
RATESTOP  
Sh. 25

POODOO  
FC-3140

Exit to POODOO  
with alarm  
code 2 1406  
"Bad return  
from ROOT-  
PSRS"

|   |  |                                |  |
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| PRGRM                                       |  | LUMINARY 1C                    |  |
| ANALST                                      |  | DOCUMENT NO.                   |  |
| DOCMR <i>W. Dwyer</i>                       |  | FC-3900                        |  |
| APPR'D <i>Rm. Euter</i>                     |  | REV                            |  |
| 3/20/69                                     |  | SHEET 12 OF 46                 |  |

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|   |  |                                |                         |
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| PRGMR _____                                 |  |                                |                         |
| ANALST _____                                |  | LUMINARY JC                    | DOCUMENT NO.<br>FC-3900 |
| DOCMR <i>W. Dwyer</i>                       |  | 11/14/67                       |                         |
| APPR'D RTH <i>W. Dwyer</i>                  |  | REV                            | SHEET 13 OF 46          |

From Preceding Sheet

$MPAC \leftarrow 2 BUF^2 + BUF$   
 $PL26 \leftarrow 3 BUF^2 + BUF$   
 $PL28 \leftarrow 4 BUF^2 + 3 BUF$   
 $PL30 \leftarrow 6 BUF^2 + 6 BUF + 1$

} Store in PUSHLIST

INTERPRET X  
 Load X1 with  
 index for target  
 parameters  
 Sh. 35

$$MPAC_V \leftarrow \left[ \frac{PL26_D \frac{RDG_V^2 X1 - RGUV}{4(TTF/8_D)} + PL28_D (VDG_V^2 X1) + MPAC_D (VGV_V)}{TTF/8_D + PL30_D (ADG_V^2 X1)} \right]^{3/4}$$

AFCCALC1

$$UNFC/2_V \leftarrow MPAC_V \times CG_M - \frac{GDT/2_V}{GSCALE_D}$$

AFCCALC2

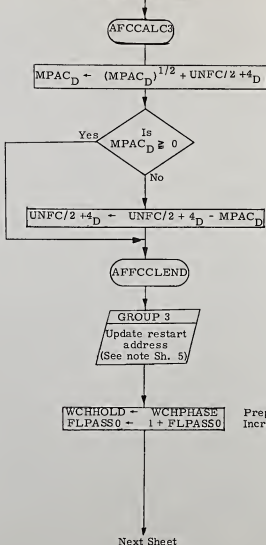
$$MPAC_D \leftarrow \left( \frac{HIGHESTF_D}{MASS_D} \right)^2 - (UNFC/2 + 2_D)^2 - (UNFC/2_D)^2$$

Is  
 $MPAC_D \geq 0$   
 ?  
 Yes

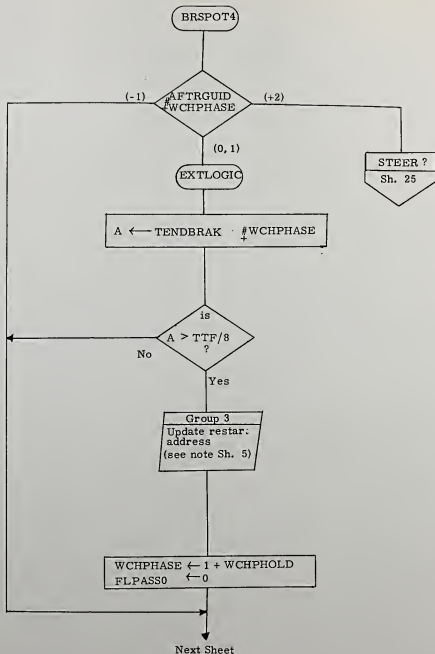
No  
 $MPAC_D \leftarrow 0$

|  |                    |                                |               |
|--|--------------------|--------------------------------|---------------|
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| PRGRM                                      |                    | DOCUMENT NO.<br>FC-3900        |               |
| ANALST                                     |                    | LUMINARY: 10                   |               |
| DOCMR                                      | <i>W. D. Smith</i> |                                |               |
| APPR'D                                     | <i>R. M. Felt</i>  | REV                            | SHEET 1 OF 46 |

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| PRGMR                                       |                    |                                |                |
| ANALST                                      |                    |                                |                |
| DOCMR                                       | <i>W. Daybird</i>  | <i>7/20/69</i>                 |                |
| APPR'D                                      | <i>R. M. Suter</i> | <i>11/25/69</i>                | REV            |
|   |                    |                                | SHEET 15 OF 46 |



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| PRGMR                                       |                     |                                | FC-3900        |
| ANALST                                      |                     |                                |                |
| DOCMR                                       | <i>W. D. Foster</i> | 9/20/69                        |                |
| APPR'D                                      | <i>R. M. Foster</i> | REV                            | SHEET 16 OF 46 |

From Preceding Sheet

CGCALC

$\frac{TTF}{8} +$   
 $\frac{TCGFBRAK+1}{TARGDEX}$   
 $\frac{WCHPHASE}{2}$

<0

>0

$\frac{TTF}{8} +$   
 $\frac{TCGFBRAK}{TARGDEX}$   
 $\frac{WCHPHASE}{2}$

>0

$\leq 0$

INTPRETX  
 Load X1 with  
 index for target  
 parameters  
 Sh. 35

$CG_V + UNIT(LAND_V)$

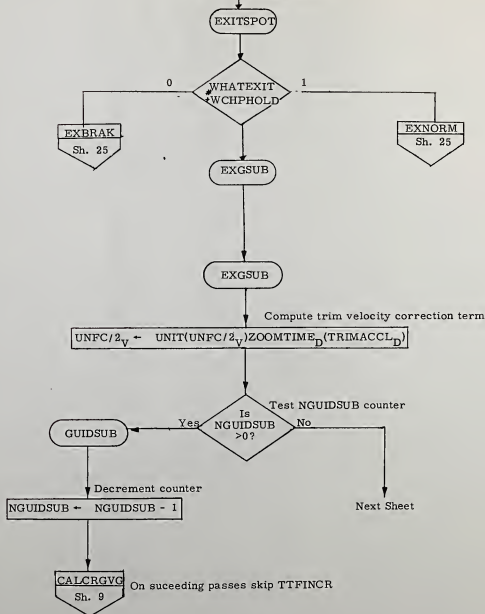
$CG + 6_V + UNIT \left\{ UNIT \left[ \frac{ANGTERMV}{TTF/8} \frac{DRAINBRAK_D}{\#1} + LAND_V - R_V \right] \times LAND_V \right\}$   
 $CG + 12_V + CG_V \times CG + 6_V$

Next Sheet

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| ANALST                                      |                    |                                |                         |
| DOCMR                                       | <i>W. B. Smith</i> |                                |                         |
| APPR'D                                      | <i>R. M. Smith</i> | REV                            | SHEET 12 OF 46          |



From Preceding Sheet



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| PRGMR _____                                 |  | DOCUMENT NO.<br>FC-3900        |                |
| ANALST _____                                |  | LUMINARY IC                    |                |
| DOCMR <i>W. L. F. Smith</i> 7/24/69         |  | REV                            | SHEET 18 OF 48 |
| APPR'D RMYE <i>W. L. F. Smith</i> 11/26/69  |  |                                |                |

From Preceding Sheet  
Test NIGNLOOP counter

Is  
NIGNLOOP  
> 0?

No

Yes

Decrement  
counter

A ← NIGNLOOP - 1

ALARM

1412  
turn on program  
alarm light and  
store alarm code

FC-3140

Descent  
ignition  
algorithm  
not con-  
verging

DDUMCALC

NIGNLOOP ← A

$PLO_D \leftarrow VGU + 4_D - 16(VGU_D)KIGNX/B^4_D$

$PL^2_D \leftarrow 1/16(RIGNZ_D - RGU + 4_D)$

$PL^4_D \leftarrow (RGU + 2_D)^2 KIGNY/B^8_D$

$PL^6_D \leftarrow (RGU_D - RIGNX_D)KIGNX/B^4_D$

$PLO_D \leftarrow \frac{(/VGU_V/ - VIGN_D)KIGNV/B^4_D + PL^6_D + PL^4_D + PL^2_D}{PLO_D (2^{10})} \Delta t_{FTP}$

$TDEC^1_D \leftarrow PLO_D + PIPTIME^1_D$

Store new  $t_{FTP}$  for next  
integration

Test  $/\Delta t_{FTP}/$

Is  
 $/PLO_D/ < 8$   
CSEC?

Yes

DDUMGOOD

Sh. 21

No

INSTALL

Test for  
availability of  
integration

FC-3350

Next Sheet

|   |  |                                |  |
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| PRGMR _____                                 |  | DOCUMENT NO.                   |  |
| ANALST _____                                |  | FC-3900                        |  |
| DOCMR <i>W. J. ...</i>                      |  | LUMINARY 1C                    |  |
| APPR'D RYM <i>E. ...</i>                    |  | REV                            |  |
| 11/15/67                                    |  | SHEET 19 OF 46                 |  |

From Preceding Sheet

Set  
INTYPFLG  
set  
MOONFLAG

Conic integration

Moon is sphere of influence

$TET_D \leftarrow PIPTIME1_D$   
 $RCV_V \leftarrow RATT1_V$   
 $VCV_V \leftarrow VATT1_V$

INTEGRVS  
Integrate LM  
state vector  
for new  $\Delta t_{FTE}$   
FC-3350

Input:  $TDEC1_D$ ,  $TET_D$ ,  $RCV_V$ ,  $VCV_V$

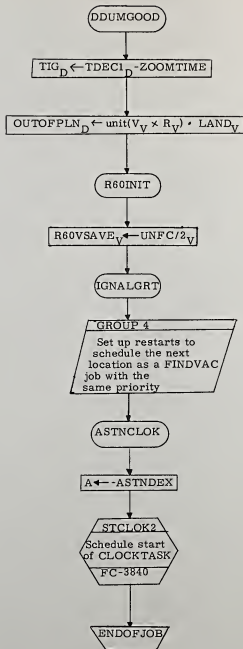
Output:  $RATT1_V$  = LM position vector

$VATT1_V$  = LM velocity vector

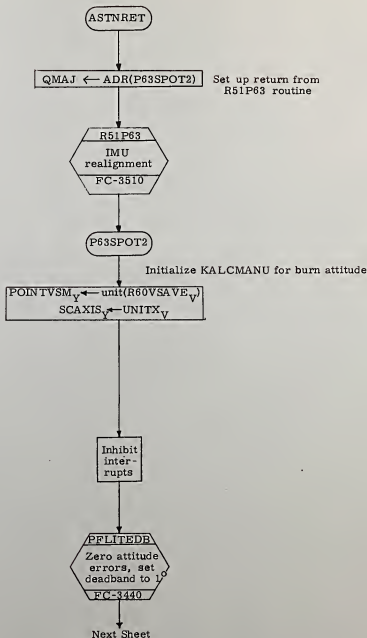
$TAT_D$  = time

IGNALOOP  
Sh. 4

|   |  |                                |  |
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| PRGMR _____                                 |  | LUMINARY 1C                    |  |
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| DOCMR <i>W. D. Smith</i> 2/24/69            |  | REV _____                      |  |
| APPR'D <i>R. M. Eubank</i>                  |  | SHEET 80 OF 140                |  |

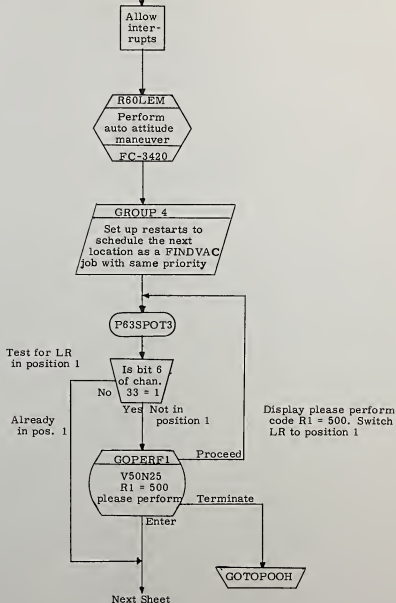


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| DOCNR <i>FC-3900</i>                        | <i>7/24/69</i>  | REV _____                      | SHEET 21 OF 46 |
| APPR'D <i>R.M. Smith</i>                    | <i>11/25/69</i> |                                |                |



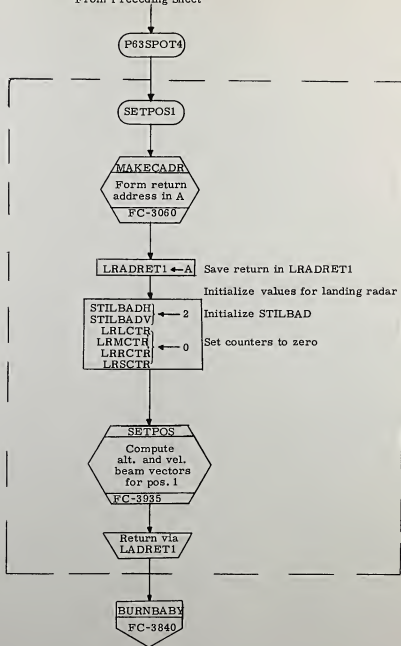
|   |                    |                                |                         |
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| PRGMR                                       |                    |                                |                         |
| ANALST                                      |                    |                                |                         |
| DOCMR                                       | <i>W. H. F. F.</i> | 1/8/69                         |                         |
| APPR'D BY                                   | <i>W. H. F. F.</i> | REV                            | SHEET 22 OF 48          |

From Preceding Sheet

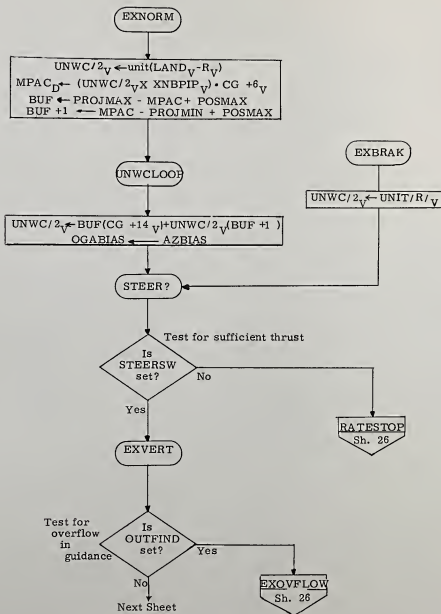


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| ANALST                                      |                  |                                |                         |
| DOCMR                                       | <i>W. J. ...</i> | REV                            | SHEET 28 OF 40          |
| APPR'D RDM Enter                            | 11/15/67         |                                |                         |

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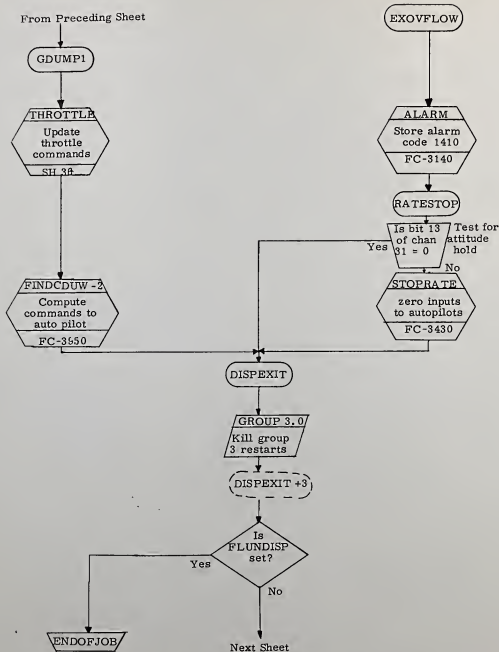
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                    | APOLLO GUIDANCE AND NAVIGATION |                |
|---|--------------------|--------------------------------|----------------|
| DRAWN                                       |                    | Lunar Landing                  |                |
| PRGMR                                       |                    | LUMINARY 10                    | DOCUMENT NO.   |
| ANALST                                      |                    |                                | FC-3900        |
| DOCNR                                       | <i>W. D. Smith</i> | 11/25/67                       |                |
| APPR'D                                      | <i>R. M. Smith</i> | 11/25/67                       | REV            |
|   |                    |                                | SHEET 24 OF 46 |



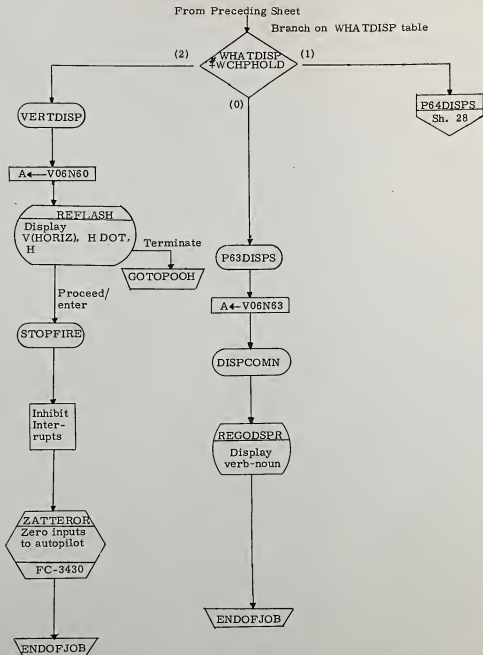
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| ANALST                                      |  | LUMINARY 1C                    |  |
| DOCMR                                       |  | REV                            |  |
| APPR'D RYM                                  |  | SHEET 25 OF 46                 |  |



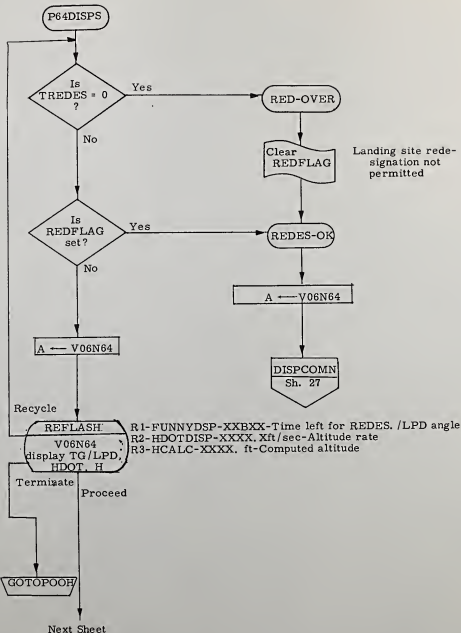
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| ANALST                                      |             |                                |                |
| DOCNR                                       | 77-10462    | 9/24/69                        |                |
| APPR'D BY                                   | RM E. Jones | 11/16/69                       | REV            |
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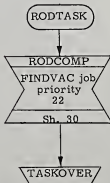
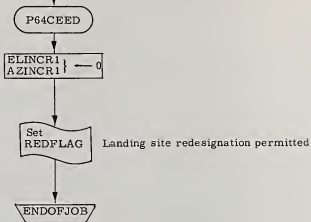


|   |                    |                                       |                |
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| PRGMR _____                                 |                    | LUMINARY 10      DOCUMENT NO. FC-3900 |                |
| ANALST _____                                |                    |                                       |                |
| DOCMR                                       | <i>H. Banforth</i> | 7/30/69                               | SHEET 27 of 46 |
| APPR'D                                      | <i>R. M. Egan</i>  | 11/25/69                              |                |
| REV _____                                   |                    |                                       |                |

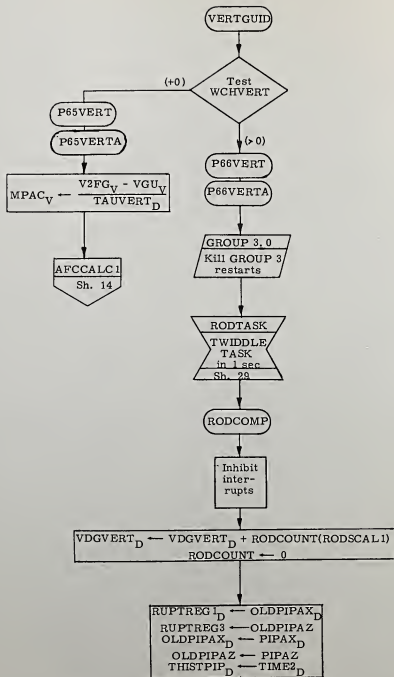


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| PRGMR                                       |  |                                |                         |
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| PRGMR                                       |  | LUMINARY 1C                    |  |
| ANALST                                      |  | DOCUMENT NO.<br>FC-3900        |  |
| DOCMR <i>W. D. Dwyer</i>                    |  | REV                            |  |
| APPR'D <i>R. M. Egan</i>                    |  | SHEET 29 OF 46                 |  |



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|   |                    | Lunar Landing                  |                         |
| DRAWN                                       |                    | REVISIONARY '1C                | DOCUMENT NO.<br>FC-3900 |
| PRGMR                                       |                    |                                |                         |
| ANALST                                      |                    | 1/24/69                        | REV                     |
| DOCMR                                       | <i>W. J. Smith</i> |                                |                         |
| APPRO'D BY                                  | <i>W. J. Smith</i> | SHEET 39 OF 46                 |                         |

From Preceding Sheet

$MPAC \leftarrow OLDPIPAX + PIPATMPX$   
 $MPAC +1 \leftarrow 0$   
 $MPAC +3 \leftarrow OLDPIPAY + PIPATMPY$   
 $MPAC +4 \leftarrow 0$   
 $MPAC +5 \leftarrow OLDPIPAZ + PIPATMPZ$   
 $MPAC +6 \leftarrow 0$

$DELVRD \leftarrow TEMX + RUPTREG1 - OLDPIPAX$   
 $DELVRD +2 \leftarrow TEMY + RUPTREG2 - OLDPIPAY$   
 $DELVRD +4 \leftarrow TEMZ + RUPTREG3 - OLDPIPAZ$

$TEMX \leftarrow 0$   
 $TEMY \leftarrow 0$   
 $TEMZ \leftarrow 0$

ITRPNT1

$PL0_V \leftarrow MPAC_V(KPIPI1_D)$   
 $PL30_D \leftarrow THISTIP_D - PIPTIME_D$   
 $PL6_D \leftarrow \frac{PL30_D}{4SEC(28)}$   
 $PL24_V \leftarrow PL0_V + (GPT/2_V - VBIAS_V)PL6_D + V_V$   
 $PL14_V \leftarrow UNIT(R_V)$   
 $HDOTDISP_D \leftarrow PL14_V \cdot PL24_V$   
 $HCA1C1_D \leftarrow PL30_D(HDOTDISP_D) + |R_V| - |LAND|_D$   
 $VDGVERT_D \leftarrow HDOTDISP_D$   
 $PL0_V \leftarrow \frac{VDGVERT_D - HDOTDISP_D}{TAUROD_D}$   
 $PL20_D \leftarrow \frac{|GDT/2_V|}{GSCALE_D}$   
 $PL0_D \leftarrow PL0_D + PL20_D$

Time since  
PIPTIME

Updated ve-  
locity

$MPAC_V \leftarrow UNITX_V$

$CDU \cdot NBSM$   
 Transform input  
vector from NB  
to SM coord.  
 FC-3320

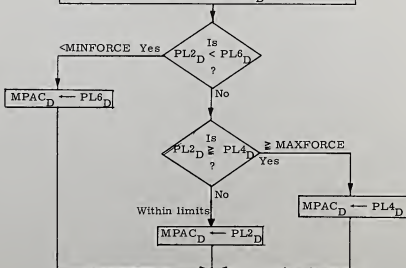
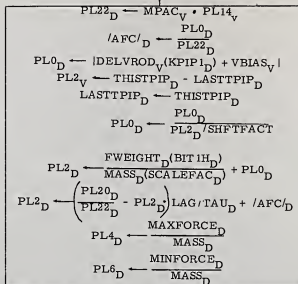
Input:  $MPAC_V$  = input vector  
in NB coordi-  
nates

Output:  $MPAC_V$  = transformed  
vector in  
SM coordi-  
nates

Next Sheet

|   |                    |                                |                         |
|---|--------------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                    | APOLLO GUIDANCE AND NAVIGATION |                         |
|   |                    | Lunar Landing                  |                         |
| DRAWN                                       |                    | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3300 |
| PRGMR                                       |                    |                                |                         |
| ANALST                                      |                    |                                |                         |
| DOCMR                                       | <i>W. R. R. R.</i> |                                |                         |
| APPR'D                                      | <i>W. R. R. R.</i> | REV                            | SHEET 31 OF 48          |

From Preceding Sheet



(AFCSPOT)

$/AFC/D \leftarrow MPAC_D$   
 $MPAC_D \leftarrow PL0_D$

Next Sheet

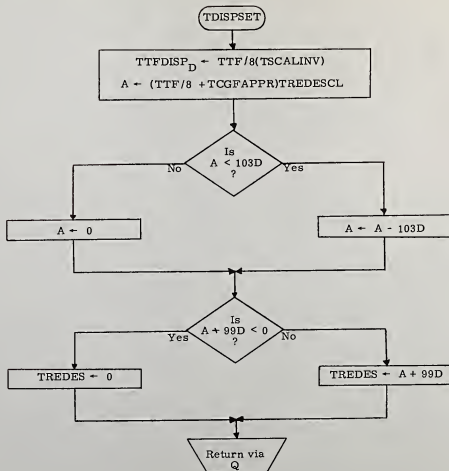
|   |                    |                                |                         |
|---|--------------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                    | APOLLO GUIDANCE AND NAVIGATION |                         |
|   |                    | Lunar Landing                  |                         |
| DRAWN                                       |                    | LUMINARY IC                    | DOCUMENT NO.<br>FC-3900 |
| PRGRM                                       |                    |                                |                         |
| ANALST                                      |                    |                                |                         |
| DOCMR                                       | <i>W. E. Smith</i> |                                |                         |
| APPR'D                                      | <i>R. W. Smith</i> | REV                            | SHEET 32 OF 46          |

From Preceding Sheet

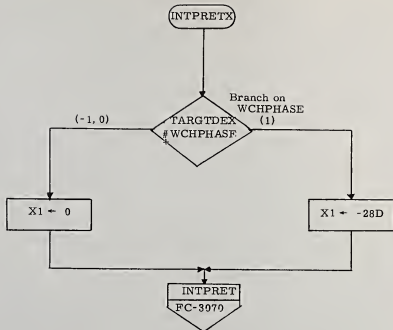


|   |          |                                |                         |
|---|----------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |          | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN _____                                 |          | Lunar Landing                  |                         |
| PRGMR _____                                 |          |                                |                         |
| ANALST _____                                |          |                                |                         |
| DOCMR <i>W. E. Evans</i> 7/31/69            |          | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3900 |
| APPR'D RYM E. Evans                         | 11/15/69 | REV                            | SHEET 83 OF 46          |

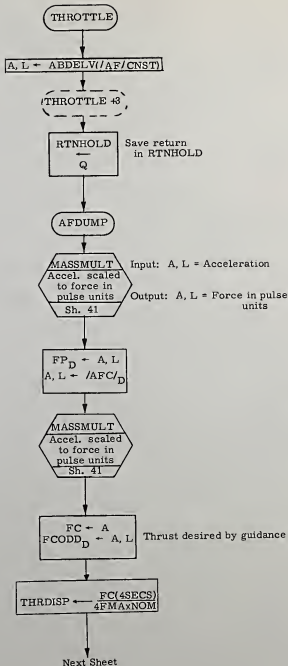




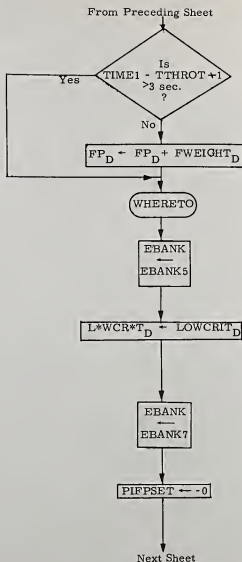
|   |  |                                |  |
|---|--|--------------------------------|--|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION |  |
| DRAWN _____                                 |  | Lunar Landing                  |  |
| PRGMR _____                                 |  | LUMINARY 1C                    |  |
| ANALST _____                                |  | DOCUMENT NO.<br>FC-3900        |  |
| DOCMR <i>W. J. ...</i>                      |  | REV _____                      |  |
| APPR'D R. M. ...                            |  | SHEET 24 OF 48                 |  |



|   |  |                                |                         |
|---|--|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN _____                                 |  | Lunar Landing                  |                         |
| PRGMR _____                                 |  |                                |                         |
| ANALST _____                                |  |                                |                         |
| DOCMR <i>W. J. Ford</i> <i>9/24/69</i>      |  | LUMINARY IC                    | DOCUMENT NO.<br>FC-3000 |
| APPR'D <i>Q. M. E. Ford</i> <i>11/15/69</i> |  | REV                            | SHEET 33 OF 46          |

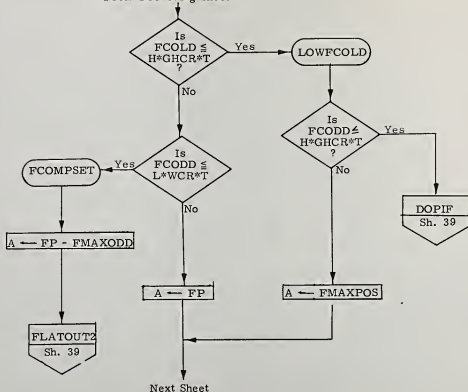


|   |                    |                                |                         |
|---|--------------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                    | APOLLO GUIDANCE AND NAVIGATION |                         |
|   |                    | Lunar Landing                  |                         |
| DRAWN                                       |                    | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3900 |
| PRGMR                                       |                    |                                |                         |
| ANALST                                      |                    |                                |                         |
| DOCNR                                       | <i>W. Benford</i>  |                                |                         |
| APPR'D                                      | <i>R. M. Euter</i> | 1/10/69<br>REV                 | SHEET 36 OF 45          |



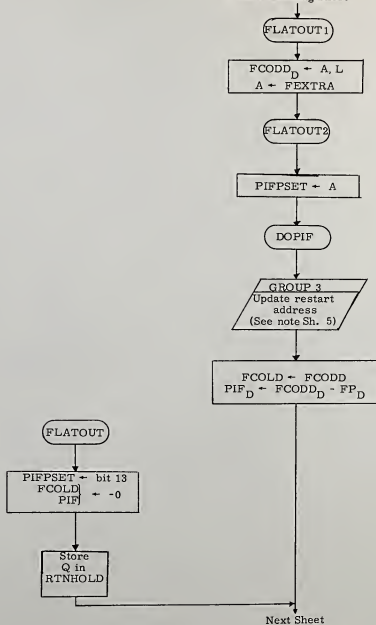
|   |                          |                                |                         |
|---|--------------------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                          | APOLLO GUIDANCE AND NAVIGATION |                         |
|   |                          | Lunar Landing                  |                         |
| DRAWN                                       |                          |                                |                         |
| PRGMR                                       |                          |                                |                         |
| ANALST                                      |                          |                                |                         |
| DOCMR                                       | <i>M. D. G. 7/24/69</i>  | LUMINARY IC                    | DOCUMENT NO.<br>FC-3900 |
| APPR'D                                      | <i>R. M. F. 11/25/69</i> | REV                            | SHEET 37 OF 46          |

From Preceding Sheet



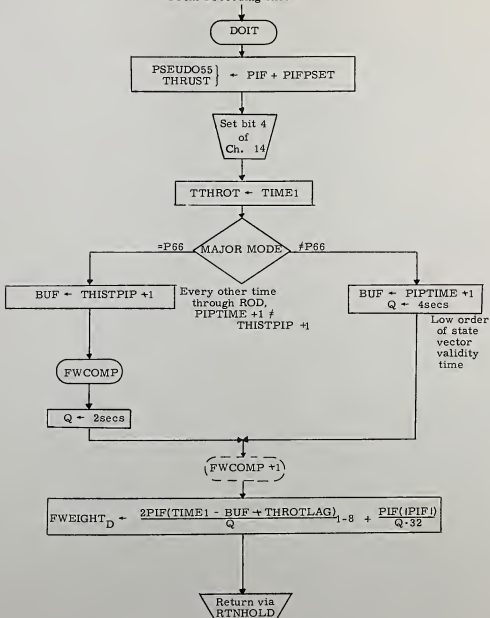
|   |                          |                                |                         |
|---|--------------------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                          | APOLLO GUIDANCE AND NAVIGATION |                         |
|   |                          | Lunar Landing                  |                         |
| DRAWN                                       |                          |                                |                         |
| PRGMR                                       |                          |                                |                         |
| ANALST                                      |                          |                                |                         |
| DOCMR                                       | <i>J. D. [Signature]</i> | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3900 |
| APPR'D                                      | <i>R. M. [Signature]</i> | REV                            | SHEET 38 OF 48          |

From Preceding Sheet

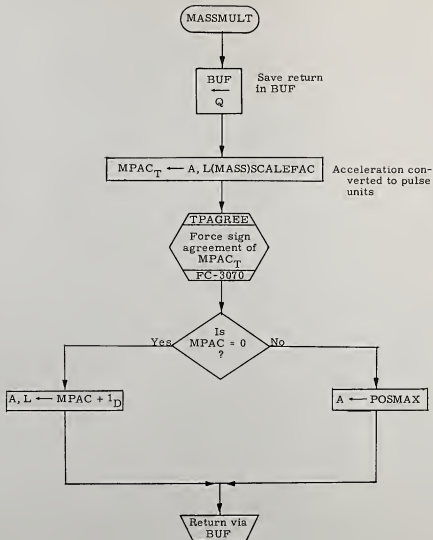


| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                      | APOLLO GUIDANCE AND NAVIGATION |                |
|---|----------------------|--------------------------------|----------------|
| DRAWN                                       |                      | Lunar Landing                  |                |
| PRGMR                                       |                      |                                |                |
| ANALST                                      |                      | LUMINARY 1C                    | DOCUMENT NO.   |
| DOCMR                                       | <i>Dr. J. H. ...</i> |                                | FC-3900        |
| APPR'D                                      | <i>Dr. J. H. ...</i> | REV                            | SHEET 39 OF 46 |

From Preceding Sheet

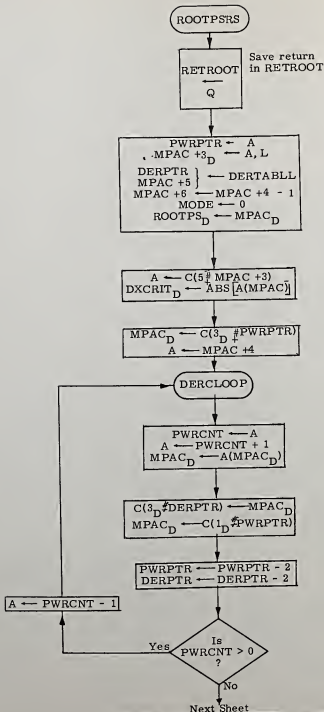


|   |  |                                |  |
|---|--|--------------------------------|--|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION |  |
| DRAWN _____                                 |  | Lunar Landing                  |  |
| PRGMR _____                                 |  |                                |  |
| ANALST _____                                |  | LUMINARY 1C                    |  |
| DOCMR <i>W. B. Smith</i> 7/5/69             |  | DOCUMENT NO.<br>FC-3900        |  |
| APPR'D <i>R. M. E. ...</i>                  |  | SHEET 4 OF 46                  |  |



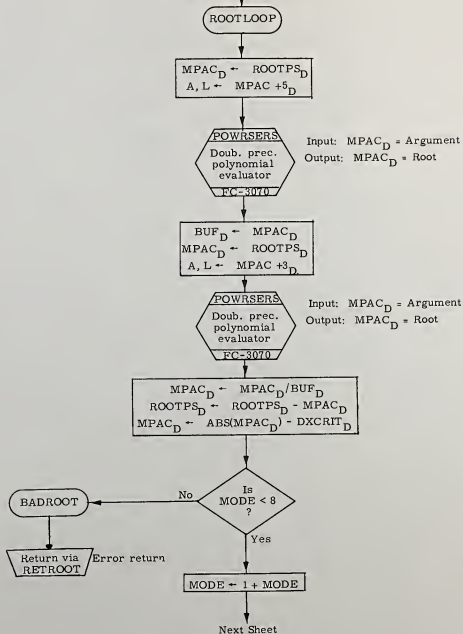
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                       | APOLLO GUIDANCE AND NAVIGATION |                |
|---|-----------------------|--------------------------------|----------------|
| DRAWN                                       |                       | Lunar Landing                  |                |
| PRGMR                                       |                       |                                | DOCUMENT NO.   |
| ANALST                                      |                       | LUMINARY-1C                    | FC-3900        |
| DOCMR                                       | <i>W. D. Griffith</i> | REV                            | SHEET 41 OF 48 |
| APPR'D                                      | <i>R. W. Evans</i>    |                                |                |



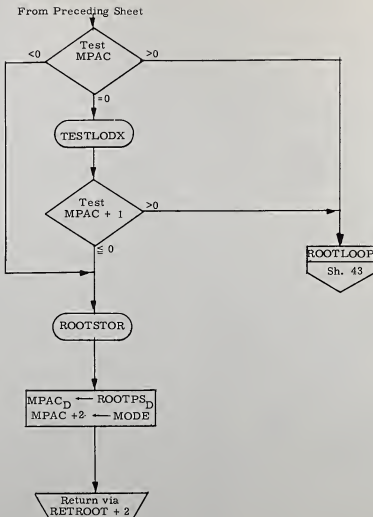


|   |  |                                |  |
|---|--|--------------------------------|--|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION |  |
| DRAWN                                       |  | Lunar Landing                  |  |
| PRGMR                                       |  | DOCUMENT NO.                   |  |
| ANALST                                      |  | FC-3900                        |  |
| DOCMR <i>W. B. Smith</i> 7/30/67            |  | LUMINARY 1C                    |  |
| APPR'D RYM <i>Smith</i> 11/24/68            |  | REV                            |  |
|   |  | SHEET 42 OF 45                 |  |

From Preceding Sheet



| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |            | APOLLO GUIDANCE AND NAVIGATION |                         |
|---|------------|--------------------------------|-------------------------|
| DRAWN                                       |            | Lunar Landing                  |                         |
| PRGMR                                       |            | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3900 |
| ANALST                                      |            |                                |                         |
| DOCMR                                       | W.C. Dwyer | 7/5/64                         |                         |
| APPR'D                                      | R.M. Evers | 7/16/64                        | REV                     |
|   |            |                                | SHEET 43 OF 48          |



|   |          |                                |                |
|---|----------|--------------------------------|----------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |          | APOLLO GUIDANCE AND NAVIGATION |                |
| DRAWN _____                                 |          | Lunar Landing                  |                |
| PRGMR _____                                 |          | DOCUMENT NO.<br>FC-3900        |                |
| ANALST _____                                |          | LUMINARY 1G                    |                |
| DOCMR <i>W. D. ...</i>                      | 9/24/69  | REV                            | SHEET 44 OF 48 |
| APPR'D <i>R. M. ...</i>                     | 10/20/69 |                                |                |

SUBROUTINES CALLED ON  
OTHER FLOWCHARTS

| Subroutine | Flowchart | Description   | Where Called   |
|------------|-----------|---|----------------|
| RO2BOTH    | FC-3220   | IMU status check  | Sh. 2          |
| RP-TO-R    | FC-3340   | Transform from planetary to basic reference system        | Sh. 3          |
| GUIDINIT   | FC-3950   | Initialize $WM_v$ and $LAND_D$                            | Sh. 3          |
| LEMPREC    | FC-3350   | Integrate LM state vector                                 | Sh. 3          |
| MUNGRAV    | FC-3850   | Compute lunar gravitational acceleration                  | Sh. 4          |
| NEWMODEX   | FC-3020   | Set new major mode  | Sh. 6          |
| C13STALL   | FC-3340   | Wait till ok to write ch. 13                              | Sh. 7          |
| PRIOCHNG   | FC-3030   | Change job priority                                       | Sh. 8          |
| ALARM      | FC-3140   | Store alarm code; turn on program alarm light             | Sh. 12, 19, 26 |
| INTSTALL   | FC-3350   | Test availability of integration                          | Sh. 19         |
| INTEGRVS   | FC-3350   | Integrate state vector                                    | Sh. 20         |
| STCLOK2    | FC-3840   | Schedule start of CLOKTASK                                | Sh. 21         |
| R51P63     | FC-3510   | IMU realignment   | Sh. 22         |
| PFLITEDB   | FC-3440   | Zero attitude errors, set deadband to $1^\circ$           | Sh. 22         |
| R6OLEM     | FC-3420   | Perform auto attitude maneuver                            | Sh. 23         |
| MAKECADR   | FC-3060   | Form return address in A                                  | Sh. 24         |
| SETPOS     | FC-3935   | Compute altitude and velocity beam vectors for position 1 | Sh. 24         |
| FINDCDUW   | FC-3950   | Compute commands to autopilot                             | Sh. 26         |
| STOPRATE   | FC-3430   | Zero inputs to autopilot                                  | Sh. 26         |
| ZATTEROR   | FC-3430   | Zero inputs to autopilot                                  | Sh. 27         |
| CDU*NBSM   | FC-3320   | Transform vector from NB to SM coordinates                | Sh. 31         |
| TPAGREE    | FC-3070   | Force sign agreement of $MPAC_T$                          | Sh. 41         |
| POWRSERS   | FC-3070   | Double precision polynomial evaluator                     | Sh. 43         |

|   |                 |                                |                |
|---|-----------------|--------------------------------|----------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                 | APOLLO GUIDANCE AND NAVIGATION |                |
| DRAWN <i>D. Lathum</i>                      | <i>11/24/67</i> | Lunar Landing                  |                |
| PRGMR                                       |                 |                                |                |
| ANALST                                      |                 |                                | DOCUMENT NO.   |
| DOCMR <i>W. B. Smith</i>                    | <i>11/25/67</i> | LUMINARY 1C                    | FC-3900        |
| APPR'D <i>R. M. Evans</i>                   | <i>11/26/67</i> | REV                            | SHEET 45 OF 46 |

# FLAGS

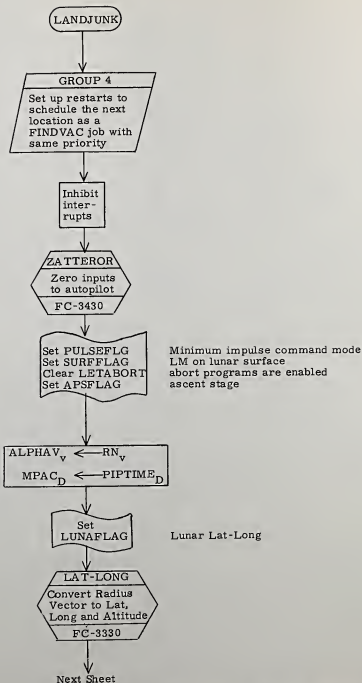
| Name                       | Meaning When Set                      | Meaning When Clear                        | Where Set | Where Cleared | Where Tested |
|----------------------------|---------------------------------------|---|-----------|---------------|--------------|
| NOTHROTL<br>Flag 5 Bit 12  | Inhibit full throttle                 | Permit full throttle                      |           | Sh. 2         |              |
| REDFLAG<br>Flag 6 Bit 6    | Landing site re-designation permitted | Landing site re-designation not permitted | Sh. 29    | Sh. 2, 7, 28  | Sh. 9, 28    |
| LRBYPASS<br>Flag 11 Bit 15 | Bypass all LR updates                 | Do not bypass LR updates                  |           | Sh. 2         |              |
| MUNFLAG<br>Flag 6 Bit 8    | SERVICER calls MUNRVG                 | SERVICER calls CALCRVG                    | Sh. 2     |               |              |
| P25 FLAG<br>Flag 0 Bit 9   | P25 operating                         | P25 not operating                         |           | Sh. 2         |              |
| RNDVZ FLG<br>Flag 0 Bit 7  | P20 running                           | P20 not running                           |           | Sh. 2         |              |
| XOVINFLG<br>Flag 13 Bit 9  | X-axis override locked out            | X-axis override okay                      |           | Sh. 6         |              |
| INTYPFLG<br>Flag 3 Bit 4   | Conic integration                     | Encke integration                         | Sh. 20    |               |              |
| MOONFLAG<br>Flag 0 Bit 12  | Moon is sphere of influence           | Earth is sphere of influence              | Sh. 20    |               |              |
| STEERSW<br>Flag 2 Bit 11   | Sufficient thrust is present          | Insufficient thrust is present            |           |               | Sh. 25       |
| FLUNDISP<br>Flag 8 Bit 10  | Current guidance displays inhibited   | Current guidance displays permitted       |           |               | Sh. 26       |

|   |          |                                |                |
|---|----------|--------------------------------|----------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |          | APOLLO GUIDANCE AND NAVIGATION |                |
| DRAWN <i>David S. Smith</i> 9/24/67         |          | Lunar Landing                  |                |
| PRGMR                                       |          | DOCUMENT NO.                   |                |
| ANALST                                      |          | LUMINARY 1C                    | FC-3900        |
| DOCMR <i>W. D. Smith</i>                    | 11/25/67 | REV                            | SHEET 46 OF 46 |
| APPR'D <i>R. M. Evers</i>                   |          |                                |                |

# LANDING CONFIRMATION

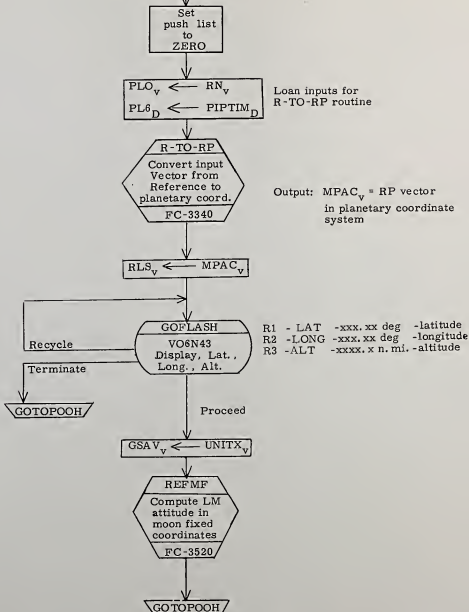
LANDJUNK Sh. 2

|   |                |                                |                         |
|---|----------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN <i>W. D. Miller</i>                   | <i>5/15/69</i> | Landing Confirmation           |                         |
| PRGMR <i>James K. Allen</i>                 | <i>5/15/69</i> | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3910 |
| ANALST                                      |                |                                |                         |
| DOCMR <i>W. D. Miller</i>                   | <i>5/15/69</i> |                                |                         |
| APPR'D <i>Robert M. Evers</i>               | <i>5/15/69</i> | REV                            | SHEET 1 OF 5            |



|   |  |                                |              |
|---|--|--------------------------------|--------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.   |  | APOLLO GUIDANCE AND NAVIGATION |              |
| DRAWN <i>James Sullivan</i> <i>DTJ</i>        |  | Landing Confirmation           |              |
| PRGMR <i>James Sullivan</i> <i>11/24/69</i>   |  | DOCUMENT NO.                   |              |
| ANALST  |  | LUMINARY IC                    | FC 3910      |
| DOCMR <i>W. D. Smith</i> <i>11/24/69</i>      |  | REV                            | SHEET 2 OF 5 |
| APPR'D <i>Robert M. Fitch</i> <i>11/24/69</i> |  |                                |              |

From Preceding Sheet



|   |  |                                |                         |
|---|--|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN <i>Don Sullivan</i> 10/16/69          |  | Landing Confirmation           |                         |
| PRGMR <i>James Brown</i> 11/14/69           |  | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3910 |
| ANALST                                      |  |                                |                         |
| DOCMR <i>W. D. Smith</i> 11/16/69           |  | REV                            | SHEET 3 OF 5            |
| APPR'D <i>Robert M. Smith</i> 11/24/69      |  |                                |                         |



# FLAGS

| Name                | Meaning When Set             | Meaning When Cleared                | Where Set | Where Cleared | Where Tested |
|---------------------|------------------------------|-------------------------------------|-----------|---------------|--------------|
| PULSEFLAG 13 BIT 15 | Minimum impulse command mode | Not in minimum impulse command mode | Sh. 2     |               |              |
| SURFLAG 8 BIT 8     | LM on lunar surface          | LM not on lunar surface             | Sh. 2     |               |              |
| LETAFLAG 9 BIT 9    | Abort programs are enabled   | Abort programs are not enabled      |           | Sh. 2         |              |
| APFLAG 10 BIT 13    | Ascent stage                 | Descent stage                       | Sh. 2     |               |              |
| LUNAFFLAG 3 BIT 12  | Lunar lat-long               | Earth lat-long                      | Sh. 2     |               |              |

|   |   |                                |                         |
|---|---|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.   |   | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN <i>James Sullivan</i> 11/21/69<br>PRGMR <i>James Sullivan</i> 11/21/69<br>ANALST<br>DOCMR <i>W. D. Griffith</i> 11/21/69<br>APPR'D <i>Robert M. Carter</i> 11/24/69 | Landing Confirmation<br><br>LUMINARY IC |                                | DOCUMENT NO.<br>FC-3910 |
| REV   |   | SHEET 4 OF 5                   |                         |

# SUBROUTINES CALLED ON OTHER FLOWCHARTS

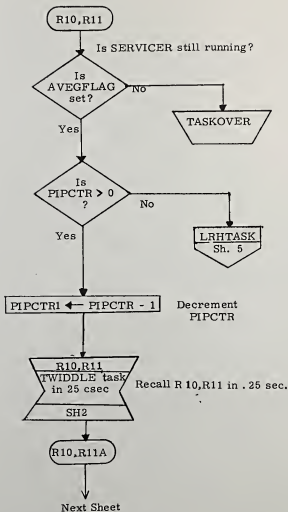
| Subroutine | Flowchart | Description                                       | Where Called |
|------------|-----------|---|--------------|
| ZATTEROR   | FC-3430   | Zero inputs to autopilot                          | Sh. 2        |
| LAT-LONG   | FC-3330   | Convert radius vector to Lat., Long. and altitude | Sh. 2        |
| R-TO-RP    | FC-3340   | Convert vector from reference to planetary        | Sh. 3        |
| REFMF      | FC-3520   | Compute LM attitude in moon fixed coordinates     | Sh. 3        |

|   |  |                                |  |
|---|--|--------------------------------|--|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS.   |  | APOLLO GUIDANCE AND NAVIGATION |  |
| DRAWN <i>W. Sullivan</i> <i>7/27/69</i>       |  | Landing Confirmation           |  |
| PRGMR <i>Francesca DiVerno</i> <i>7/27/69</i> |  | DOCUMENT NO.                   |  |
| ANALST <i>W. Sullivan</i> <i>7/27/69</i>      |  | LUMINARY 1C FC-3910            |  |
| DOCMR <i>W. Sullivan</i> <i>7/27/69</i>       |  | REV                            |  |
| APPR'D <i>Robert M. Felt</i> <i>7/27/69</i>   |  | SHEET 5 OF 5                   |  |

R09, R10, R11

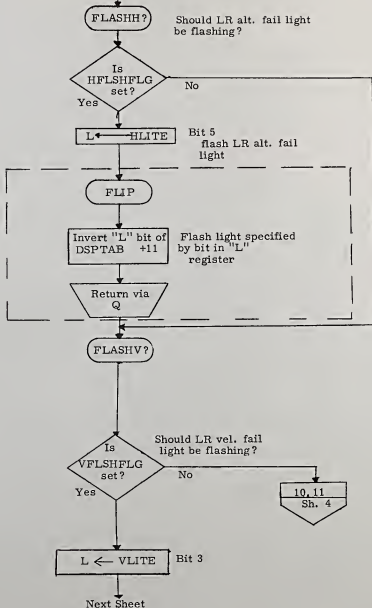
|          |       |
|----------|-------|
| R10, R11 | Sh. 2 |
| FLIP     | Sh. 3 |
| 10, 11   | Sh. 4 |
| LRHTASK  | Sh. 5 |
| LRHJOB   | Sh. 6 |
| HBAD     | Sh. 7 |
| LANDISP  | Sh. 8 |

|   |  |                                |         |
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| PRGMR <i>Bob Bernick</i> 11/24/69           |  | DOCUMENT NO.                   |         |
| ANALST                                      |  | LUMINARY 1C                    | FC-3930 |
| DOCMR <i>W. Dwyer</i> 11/21/69              |  | REV 1                          |         |
| APPR'D <i>Robert M. Smith</i> 11/25/69      |  | SHEET 1 OF 24                  |         |



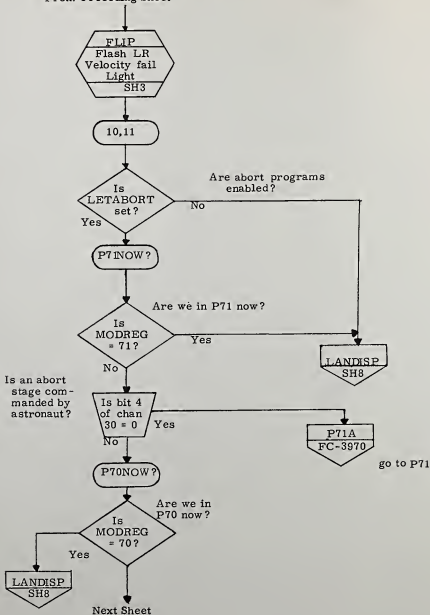
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| DRAWN <i>R. F. Smith</i> 1/22/69            |  | R09, R10, R11                  |         |
| PRGRM <i>R. F. Smith</i> 1/22/69            |  | DOCUMENT NO.                   |         |
| ANALST                                      |  | LUMINARY IC                    | FC-5550 |
| DOCHR <i>R. F. Smith</i> 1/22/69            |  | REV 1                          |         |
| APPR'D <i>R. F. Smith</i> 1/22/69           |  | SHEET 2 OF 24                  |         |

From Preceding Sheet

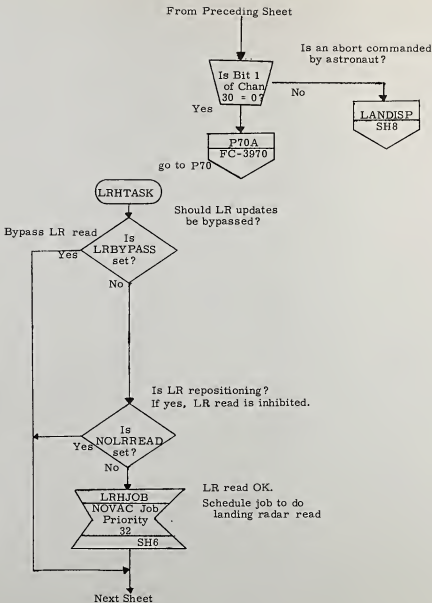


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| DRAWN <i>D. L. S. Smith</i> 7/26/67         |  | R09, R10, R11                  |  |
| PRGMR <i>D. L. S. Smith</i> 10/26/67        |  | IsUMINARY 1C                   |  |
| ANALST <i>H. B. Smith</i> 7/26/67           |  | DOCUMENT NO.<br>FC-3930        |  |
| DOCMR <i>H. B. Smith</i> 7/26/67            |  | REV 1                          |  |
| APPR'D <i>R. J. M. Smith</i> 10/26/67       |  | SHEET 3 OF 24                  |  |

From Preceding Sheet

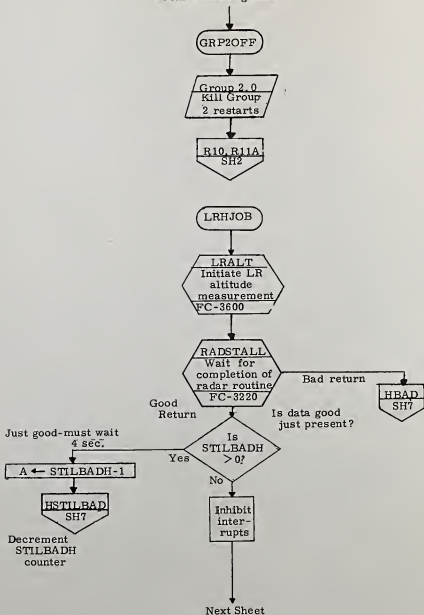


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| DRAWN <i>P. J. ...</i>                      |  | R09, R10, R11                  |  |
| PRGMR <i>P. J. ...</i>                      |  | LUMINARY 1C                    |  |
| ANALST                                      |  | DOCUMENT NO.<br>FC-3930        |  |
| DOCMR <i>W. J. ...</i>                      |  | REV 1                          |  |
| APPR'D <i>P. J. ...</i>                     |  | SHEET 4 OF 24                  |  |



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| DRAWN <i>Edith K. Smith</i> 10/24/69        |  | R09, R10, R11                  |              |
| PRGMR <i>Edith K. Smith</i> 10/24/69        |  | LUMINARY 1C                    | DOCUMENT NO. |
| ANALST <i>Edith K. Smith</i> 10/24/69       |  |                                | FC-3930      |
| DOCMR <i>Edith K. Smith</i> 10/24/69        |  | REV 1                          |              |
| APPR'D <i>Robert M. Smith</i> 10/24/69      |  | SHEET 5 of 24                  |              |

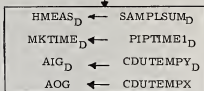
From Preceding Sheet



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| DRAWN <i>D. L. Smith</i> 2/2/69             |  | R09, R10, R11                  |                         |
| PRGRM <i>RF-3600</i> 10/21/69               |  |                                |                         |
| ANALST                                      |  | LUMINARY 1C                    | DOCUMENT NO.<br>Fc-3930 |
| DOCMR <i>W. England</i> 7/26/69             |  |                                |                         |
| APPROVED <i>W. England</i> 7/26/69          |  | REV 1                          | SHEET 6 OF 24           |



From Preceding Sheet



Set  
RNGEDATA

LR altitude  
measurement made

ENDLRH

ENDOFJOB

HEAD

Reset STILBADH counter  
to wait 4 sec.

Has scale change  
occurred during  
RR reading

No

Is  
RNGSCFLG  
set?

Yes

HSTILBAD-1

A ← 2

HSTILBAD

STILBADH ← A

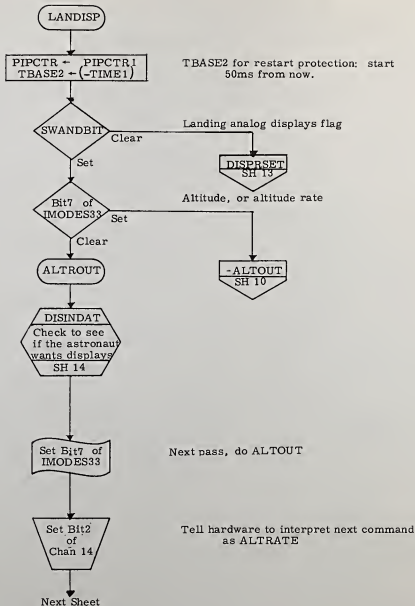
ENDOFJOB

clear  
RNGSCFLG

No scale  
change has  
occurred  
during RR  
reading

ENDOFJOB

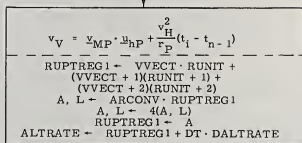
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| DRAWN <i>R. H. Smith</i> 1/26/67            |  | R09, R10, R11                  |               |
| PROGRM <i>R. Bernstein</i> 1/26/67          |  | LUMINARY 1C                    | DOCUMENT NO.  |
| ANALST <i>W. C. Haglund</i> 1/26/67         |  |                                | FC 3930       |
| DOCMR <i>R. M. Smith</i> 1/26/67            |  | REV 1                          | SHEET 7 OF 24 |



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| DRAWN <i>John R. ...</i>                    |  | R09, R10, R11                  |                         |
| PRGRM <i>APC Br... 190/18</i>               |  | LUMINARY 1C                    | DOCUMENT NO.<br>FC-5930 |
| ANALST                                      |  |                                |                         |
| DOCNR <i>W. ...</i>                         |  | REV 1                          | SHEET 8 OF 24           |
| APPR'D <i>...</i>                           |  |                                |                         |

From Preceding Sheet

ARCOMP



(3. 4. 4. 7)

<0 ALTRATE ≥ 0

A ← (-ALTRATE)

A ← Bit 15 + ALTRATE

DATAOUT

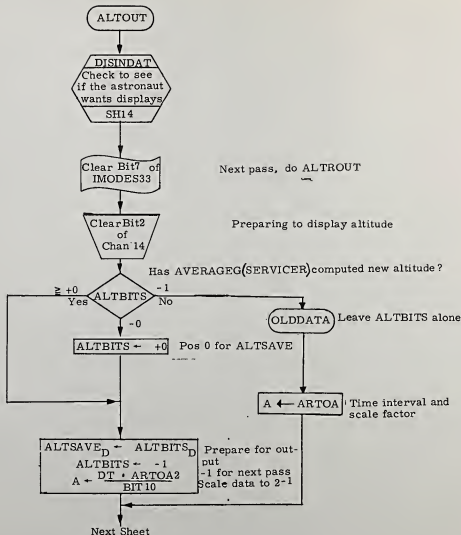
ALTM ← A

Set Bit 3 of  
Chan 14

Drive the tape meter.  
Command to display altitude or  
altitude rate, depending on Bit 2  
of Chan 14.

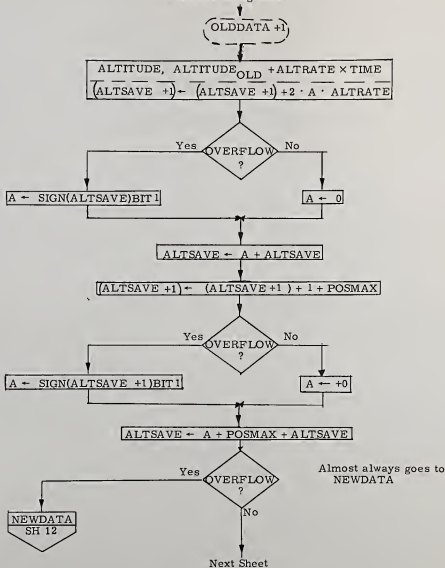
TASKOVER

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|---|-----------------|--------------------------------|---------------|
| DRAWN <i>R. L. Thayer</i>                   | <i>9/24/69</i>  | R09, R10, R11                  |               |
| PRGMR <i>R. L. Thayer</i>                   | <i>10/24/69</i> | LUMINARY 1C                    | DOCUMENT NO.  |
| ANALST                                      |                 |                                | FC - 3930     |
| DOCNR <i>W. Englund</i>                     | <i>9/24/69</i>  | REV 1                          | SHEET 9 of 24 |
| APPRO'D <i>W. Englund</i>                   | <i>10/24/69</i> |                                |               |



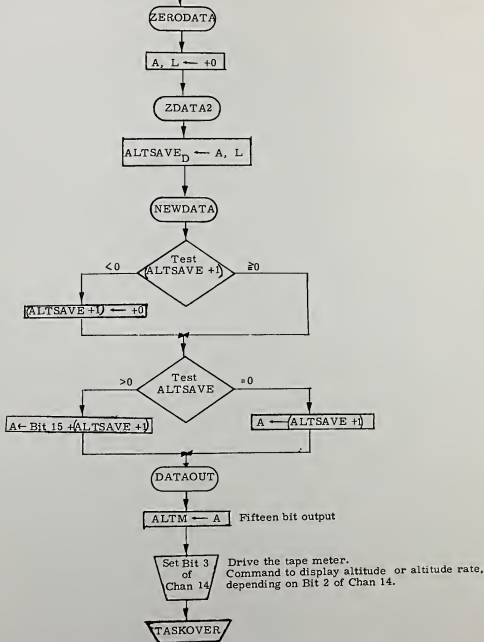
|   |  |                                |  |
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| DRAWN <i>[Signature]</i> 1/4/69             |  | R09, R10, R11                  |  |
| PRGRM <i>[Signature]</i> 1/4/69             |  | DOCUMENT NO.<br>FC-3890        |  |
| ANALST <i>[Signature]</i> 1/4/69            |  | LUMINARY 1C                    |  |
| BOCMR <i>[Signature]</i> 1/4/69             |  | REV 1                          |  |
| APPR'D <i>[Signature]</i> 1/4/69            |  | SHEET 10 OF 24                 |  |

From Preceding Sheet

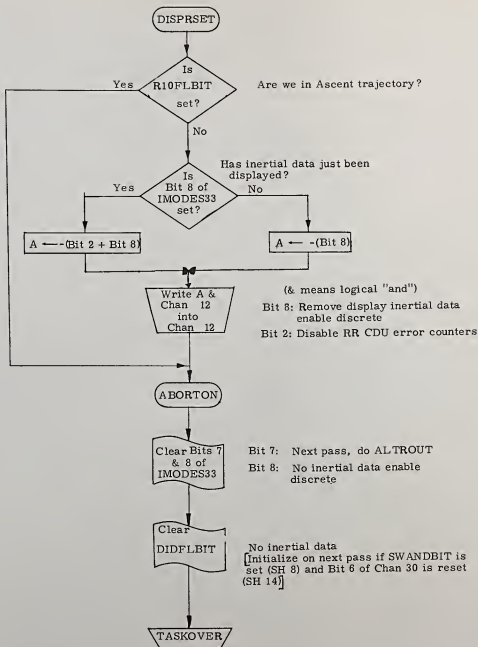


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| DRAWN <i>John B. Blythe</i> 1/24/69         |  | R09, R10, R11                  |                |
| PRGMR <i>John B. Blythe</i> 1/25/69         |  |                                |                |
| ANALST                                      |  | LUMINARY 1C                    | DOCUMENT NO.   |
| DOCNR <i>11-10-69</i> 9/24/69               |  |                                | FC-3930        |
| APPR'D <i>J. B. Blythe</i> 1/24/69          |  | REV 1                          | SHEET 11 OF 24 |

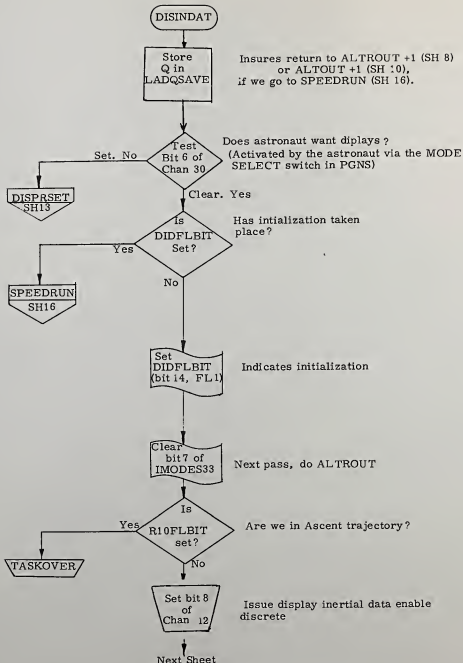
From Preceding Sheet



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| PRGMR <i>[Signature]</i> 10/21/69           |  | DOCUMENT NO.                   |                |
| ANALST                                      |  | LUMINARY 1C                    | PC-5930        |
| DOCMR <i>[Signature]</i> 9/26/69            |  | REV 1                          | SHEET 12 OF 24 |
| APPROVAL <i>[Signature]</i>                 |  |                                |                |



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| PRGMR <i>[Signature]</i>                    | <i>[Signature]</i> | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3930 |
| ANALST <i>[Signature]</i>                   | <i>[Signature]</i> |                                |                         |
| DOCMR <i>[Signature]</i>                    | <i>[Signature]</i> | REV 1                          | SHEET 13 OF 24          |



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| DRAWN <i>J. Hildner</i> 7/6/69              |  | R09, R10, R11                  |         |
| PRGMR <i>D. Brumfield</i> 10/21/69          |  | DOCUMENT NO.                   |         |
| ANALST                                      |  | LUMINARY 1C                    | FC-3930 |
| DOCMR <i>M. Dwyer</i> 7/6/69                |  | REV 1                          |         |
| APPR'D <i>R. D. M. Carter</i> 10/21/69      |  | SHEET 14 of 24                 |         |



From Preceding Sheet

TRAKLATV ← +0  
TRAKFWDV ← +0  
LATVMETR ← +0  
FORVMETR ← +0

INTLZE  
TWIDDLE Task  
in 8csec.  
SH 15

TASKOVER

INTLZE

Set Bit 2  
of  
Chan 12

Enable RR CDU error counters

Set  
Bit 8 of  
IMODES33

Indicate display inertial data enable discrete was issued.

TASKOVER

|   |          |                                |                         |  |
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| PRGMR <i>[Signature]</i>                    | 10/29/69 | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3930 |  |
| ANALST <i>[Signature]</i>                   | 9/26/69  |                                |                         |  |
| DOCMR <i>[Signature]</i>                    | 9/26/69  | REV 1                          |                         |  |
| APPR'D <i>[Signature]</i>                   | 10/29/69 | SHEET 15 OF 24                 |                         |  |

SPEEDRUN

$$\begin{aligned} \frac{v_{MP_x} - v_{MP}}{DT} &= \frac{v_P(t-t_N) + (\Delta v_P + \Delta v_{P_N})(t-t_N)}{DT} \quad \text{X component} \\ DT &= \text{Bit 14} + \text{Bit 14} + \text{TIME1} - (\text{PIPTIME} + 1) \\ &\quad \text{ITEMP5} + 1\text{SEC} \\ VVECT_S &= DT \left[ \frac{4(GDT/2)_D}{ITEMP5} \right] \\ VVECT_S &= VVECT_S + 4(V_D) \\ VVECT_S &= VVECT_S + KPIP1(5) (PIPATMPX + PIPAX) \end{aligned}$$

$$\begin{aligned} (VVECT + 1) &= DT \left[ \frac{4(GDT/2 + 2)_D}{ITEMP5} \right] \quad \text{Y component} \\ (VVECT + 1) &= (VVECT + 1) + 4(V + 2)_D \\ (VVECT + 1) &= (VVECT + 1) + KPIP1(5) (PIPATMFY + PIPAY) \end{aligned}$$

$$\begin{aligned} (VVECT + 2) &= DT \left[ \frac{4(GDT/2 + 4)_D}{ITEMP5} \right] \quad \text{Z component} \\ (VVECT + 2) &= (VVECT + 2) + 4(V + 4)_D \\ (VVECT + 2) &= (VVECT + 2) + KPIP1(5) (PIPATMPZ + PIPAZ) \end{aligned}$$

VARDELAY  
delay 4 csec  
FC-3040

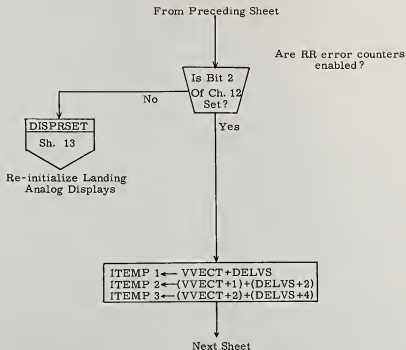
Is R10FLBIT set? Are we in Ascent trajectory?

Yes  
Return via  
LADQSAVE

No: compute FORVEL and LATVEL

Next Sheet

|   |         |                                |                |
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| PRGMR <i>[Signature]</i> 1/15/68            |         | DOCUMENT NO.                   |                |
| ANALST                                      |         | LUMINARY 1C                    | FC-3930        |
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| APPR'D <i>[Signature]</i>                   | 1/23/68 |                                |                |



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| PRGMR <i>R. B. Smith</i> 11/25/69           |  |                                | DOCUMENT NO.   |
| ANALST                                      |  | LUMINARY 1C                    | FC-3930        |
| DOCMR <i>W. D. Smith</i> 11/25/69           |  | REV 1                          | SHEET 17 OF 24 |
| APPR'D <i>Robert M. Smith</i> 11/25/69      |  |                                |                |

From Preceding Sheet

$$\begin{aligned} v_{HY} &= \frac{v_{MP}}{u_{HYP}} \\ RUPTREG1 &\leftarrow UHYP(IEMP1) \\ RUPTREG1 &\leftarrow RUPTREG1 + ITEMP2(UHYP + 2) \\ RUPTREG1 &\leftarrow RUPTREG1 + ITEMP3(UHYP + 4) \\ VH Y &\leftarrow 2(RUPTREG1) \end{aligned}$$

Velocity directed along  
the Y-coordinate

$$\begin{aligned} v_{HZ} &= \frac{v_{MP}}{u_{HZP}} \\ RUPTREG1 &\leftarrow UHZP(IEMP1) \\ RUPTREG1 &\leftarrow RUPTREG1 + (UH ZP + 2)ITEMP2 \\ RUPTREG1 &\leftarrow RUPTREG1 + (UH ZP + 4)ITEMP3 \\ VH Z &\leftarrow 2(RUPTREG1) \end{aligned}$$

Velocity directed along  
the Z-coordinate

GET22/32

$$\begin{aligned} EBANK &\leftarrow EBANK6 \\ ITEMP3 &\leftarrow M22 \\ ITEMP4 &\leftarrow M32 \\ EBANK &\leftarrow EBANK7 \end{aligned}$$

$\sin(AOG)$   
 $\cos(AOG)$  } computed by T4RUPT  
every 0.25 sec

LATFWDV

$$\begin{aligned} v_{HL} &= v_{HZ} \sin AOG + v_{HY} \cos AOG \\ RUPTREG1 &\leftarrow ITEMP4(VHY) \\ RUPTREG1 &\leftarrow RUPTREG1 + ITEMP3(VHZ) \\ LATVEL &\leftarrow 2(RUPTREG1) VELCONV \end{aligned}$$

$$\begin{aligned} v_{HF} &= v_{HZ} \cos AOG - v_{HY} \sin AOG \\ RUPTREG1 &\leftarrow ITEMP4(VHZ) \\ RUPTREG1 &\leftarrow RUPTREG1 - (VHY)ITEMP3 \\ FORVEL &\leftarrow 2(RUPTREG1) VELCONV \end{aligned}$$

$$\begin{aligned} ITEMP6 &\leftarrow (-MAXVBITS) \\ A &\leftarrow ONE \end{aligned}$$

-200 ft/sec  
For loop control: 2 times through

Next Sheet

|   |  |                                |              |                |
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| PRGMR <i>L. L. L. L.</i> 7/14/68            |  | LUMINARY 1C                    | DOCUMENT NO. |                |
| ANALST <i>L. L. L. L.</i> 7/14/68           |  |                                | FC-3930      |                |
| DOCNR <i>L. L. L. L.</i> 7/14/68            |  |                                | REV 1        | SHEET 18 OF 24 |
| APPR'D <i>L. L. L. L.</i> 7/14/68           |  |                                |              |                |

From Preceding Sheet

VMONITOR

Forward and Lateral  
velocity monitor

ITEMP5 ← A

>0

Test  
|LATVEL|  
ITEMP5

First time: FORVEL  
Second time: LATVEL

=0

Yes

|LATVEL|  
ITEMP5 ≥  
MAXVBITS  
?

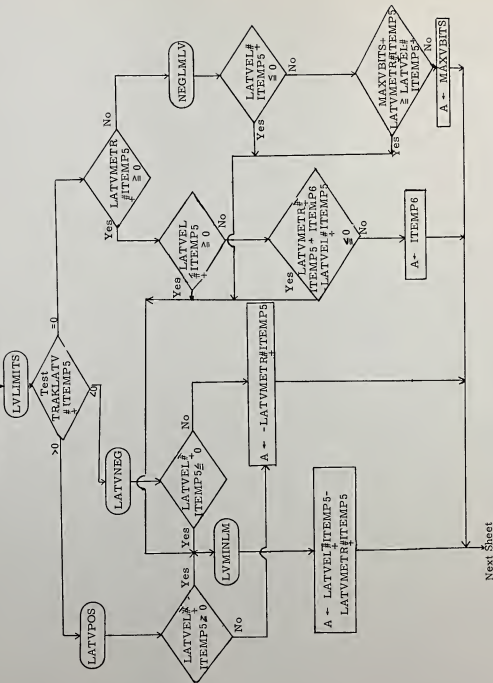
No

CHKLASTY  
SH 21

Next Sheet

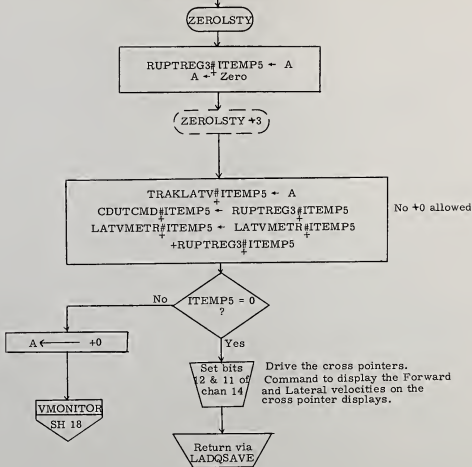
|   |          |                                |                |
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| DRAWN <i>E. Suber</i> 4/26/69               |          | R09, R10, R11                  |                |
| PRGMR <i>W. B. Smith</i> 4/23/69            |          |                                |                |
| ANALST                                      |          | LUMINARY 1C                    | DOCUMENT NO.   |
| DOCMR <i>W. B. Smith</i>                    | 7/26/69  |                                | FC 3930        |
| APPR'D <i>R. M. F. Jones</i>                | 12/25/69 | REV 1                          | SHEET 19 OF 24 |

From Preceding Sheet

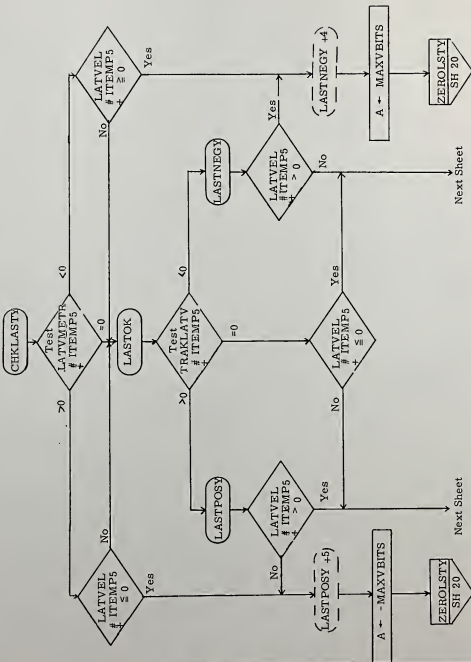


|   |          |                                |                         |
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| DRAWN <i>John P. Smith</i>                  | 9/24/69  | R09, R10, R11                  |                         |
| PRGMR <i>W. P. Smith</i>                    | 10/29/69 |                                |                         |
| ANALST                                      |          | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3930 |
| DOCNR                                       | 9/24/69  |                                |                         |
| APPRD <i>R. M. Evers</i>                    | 10/29/69 | REV 1                          | SHEET 20 of 24          |

From Preceding Sheet

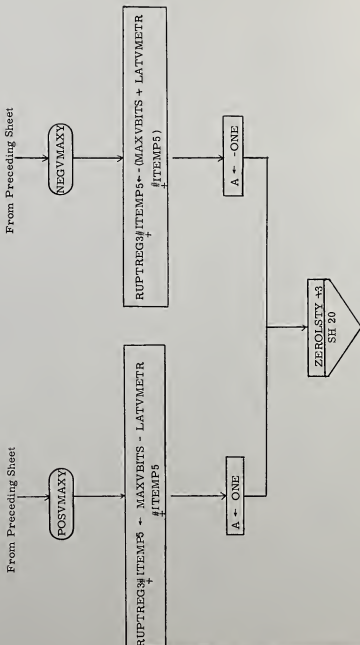


|   |                |                                |                |
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| DRAWN <i>J. L. ...</i>                      | <i>1/10/69</i> |                                |                |
| PRGMR <i>R. L. ...</i>                      | <i>1/10/69</i> | LUMINARY 1C                    | DOCUMENT NO.   |
| ANALST                                      |                |                                | FC-3930        |
| DOCMR <i>M. ...</i>                         | <i>2/10/69</i> |                                |                |
| APPR'D <i>...</i>                           | <i>2/10/69</i> | REV 1                          | SHEET 21 of 24 |



|   |                              |                                |                         |
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| DRAWN <i>P. J. H. H. H.</i>                 |                              | R09, R10, R11                  |                         |
| PRGMR <i>P. J. H. H. H.</i>                 |                              |                                |                         |
| ANALST                                      | DOCNR                        | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3930 |
| APPR'D <i>P. J. H. H. H.</i>                | ENTR'D <i>P. J. H. H. H.</i> | REV 1                          | SHEET 22 OF 24          |





|   |  |                                |                         |
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| DRAWN <i>Robert R. R. 7/6/69</i>            |  | R09, R10, R11                  |                         |
| PRGRM <i>APOLLO Guidance 10/2/69</i>        |  |                                |                         |
| ANALST                                      |  |                                |                         |
| DCMR <i>W. R. R. 7/6/69</i>                 |  | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3930 |
| APPR'D <i>R. M. R. 7/29/69</i>              |  | REV 1                          | SHEET 23 OF 24          |

## SUBROUTINES CALLED ON OTHER FLOWCHARTS

| Subroutine | Flowchart | Description                          | Where Called |
|------------|-----------|--------------------------------------|--------------|
| LRLALT     | FC-3600   | Initiate LR altitude measurement     | Sh. 6        |
| RADSTALL   | FC-3220   | Wait for completion of radar routine | Sh. 6        |

## FLAG

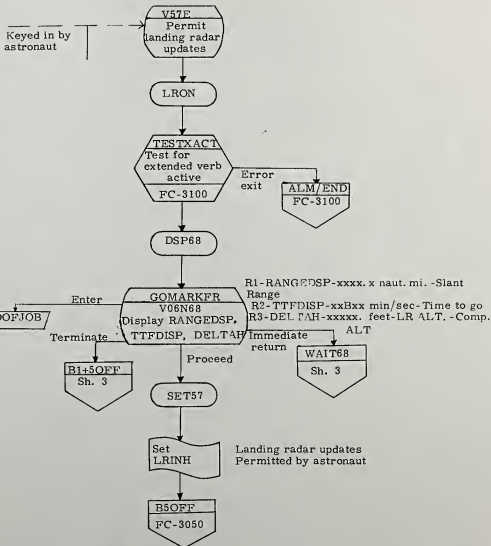
| Name                       | Meaning When Set   | Meaning When Cleared   | Where Set | Where Cleared | Where Tested   |
|----------------------------|--|--|-----------|---------------|----------------|
| AVEGFLAG<br>Flag 7 Bit 5   | Average (SERVICER) desired                                 | Average (SERVICER) not desired   |           |               | Sh. 2          |
| HFLSHFLG<br>Flag 11 Bit 1  | LR altitude fail lamp should be flashing                   | LR altitude fail lamp should not be flashing                               |           |               | Sh. 3          |
| VFLSHFLG<br>Flag 11 Bit 2  | LR velocity fail lamp should be flashing                   | LR velocity fail lamp should not be flashing                               |           |               | Sh. 3          |
| LETABORT<br>Flag 9 Bit 9   | Abort programs are enabled                                 | Abort programs are not enabled   |           |               | Sh. 4          |
| LRBYPASS<br>Flag 11 Bit 15 | Bypass all landing radar updates                           | Do not bypass landing radar updates  |           |               | Sh. 5          |
| NOLRREAD<br>Flag 11 Bit 10 | Landing radar repositioning                                | Landing radar not repositioning  |           |               | Sh. 5          |
| RNGEDATA<br>Flag 11 Bit 4  | LR altitude measurement made                               | LR altitude measurement not made   | Sh. 7     |               |                |
| RNGSCFLG<br>Flag 5 Bit 10  | Scale change has occurred during RR reading                | No scale change has occurred during RR reading                             |           | Sh. 7         |                |
| R10FLAG<br>Flag 0 Bit 2    | R10 outputs data to altitude and altitude rate meters only | Besides output when set, also to forward and lateral velocity crosspointer |           |               | Sh. 13, 14, 16 |
| D1DFLAG                    | Inertial data is available                                 | Perform data display initialization functions                              | Sh. 14    | Sh. 13        | Sh. 14         |

|   |                 |                                |                         |
|---|-----------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                 | APOLLO GUIDANCE AND NAVIGATION |                         |
|   |                 | R09, R10, R11                  |                         |
| DRAWN <i>D. Sander</i>                      | <i>10/20/69</i> |                                |                         |
| PGRAM <i>D. Sander</i>                      | <i>11/15/69</i> |                                |                         |
| ANALST                                      |                 | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3930 |
| DOCMR <i>M. D. Smith</i>                    | <i>11/15/69</i> |                                |                         |
| APPR'D <i>R. W. Fouts</i>                   | <i>10/29/69</i> | REV 1                          | SHEET 24 OF 24          |

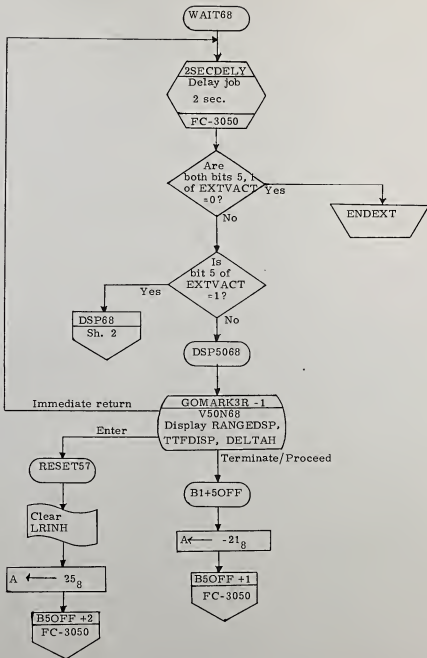
R12 - DESCENT STATE VECTOR UPDATE  
MAJOR SUBROUTINES ON THIS CHART

|          |       |
|----------|-------|
| VERB57   | Sh. 2 |
| VERB58   | Sh. 4 |
| VERB59   | Sh. 4 |
| RDRUSECK | Sh. 6 |
| LRPOS2   | Sh. 7 |
| MUNRETRN | Sh. 9 |

|   |                 |                                      |                         |
|---|-----------------|--------------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                 | APOLLO GUIDANCE AND NAVIGATION       |                         |
|   |                 | R12 - Descent State<br>Vector Update |                         |
| DRAWN <i>R. Wachs</i>                       | <i>10/29/69</i> | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| PRGMR <i>D. Moore</i>                       | <i>12/1/69</i>  |                                      |                         |
| ANALST                                      |                 |                                      |                         |
| DOCMR <i>R. E. Smith</i>                    | <i>11/30/69</i> |                                      |                         |
| APPR'D <i>Robert M. Smith</i>               | <i>11/1/69</i>  | REV 0                                | SHEET 1 OF 36           |

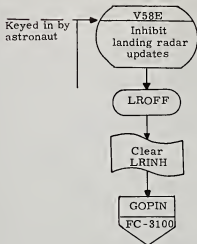


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|---|-----------------|---------------------------------------|------------------------|
| DRAWN                                       | <i>G. Welch</i> | R. 2 - Descent State<br>Vector Update |                        |
| PRGMR                                       | <i>R. Moore</i> |                                       |                        |
| ANALST                                      |                 | 11M: 1C                               | DOCUMENT NO.<br>7-3004 |
| DOCMR                                       | <i>R. Moore</i> | REV 0                                 | SHEET 2 OF 36          |
| APPR'D                                      | <i>R. Moore</i> |                                       |                        |



|   |  |                                      |                        |
|---|--|--------------------------------------|------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION       |                        |
| DRAWN <i>[Signature]</i> 1/29/68            |  | R12 - Descent State<br>Vector Update |                        |
| PRGMR <i>[Signature]</i> 1/31/68            |  | LIMIT: AR 1C                         | DOCUMENT NO.<br>C-3935 |
| ANALST <i>[Signature]</i> 1/30/68           |  |                                      |                        |
| DOCMR <i>[Signature]</i> 1/30/68            |  | REV 0                                |                        |
| APPR'D <i>[Signature]</i> 2/1/68            |  | SHEET 3 OF 36                        |                        |

# EXTENDED VERB 58

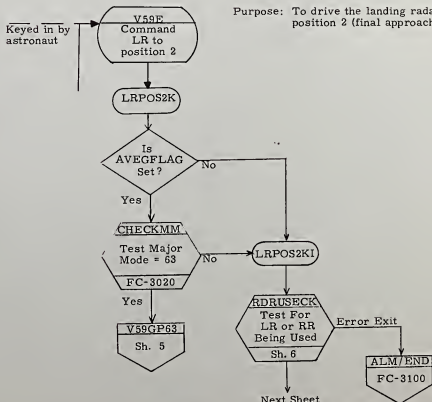


Purpose: To inhibit the incorporation of landing radar data during descent state vector update

Landing radar updates inhibited by astronaut

Exit via GOPIN

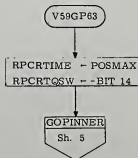
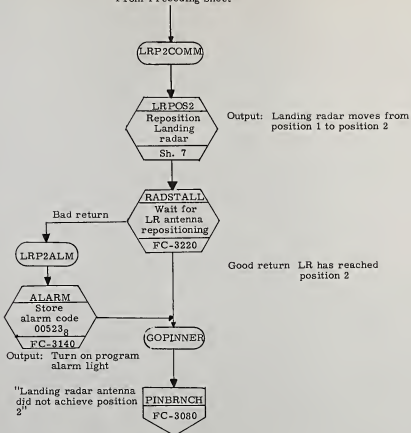
# EXTENDED VERB 59



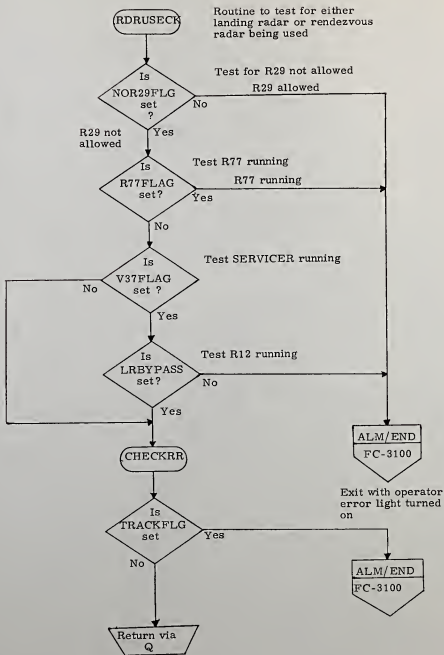
Purpose: To drive the landing radar to position 2 (final approach)

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|---|--|--------------------------------------|-------------------------|
| DRAWN <i>G. White</i> 12/4/69               |  | R12 - Descent State<br>Vector Update |                         |
| PRGMR <i>B. Moore</i> 12/4/69               |  | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| ANALST <i>H. Danforth</i> 12/4/69           |  |                                      |                         |
| DOCMR <i>R. Moore</i> 12/4/69               |  | REV 0                                |                         |
| APPR'D <i>R. Moore</i> 12/4/69              |  | SHEET 4 OF 36                        |                         |

From Preceding Sheet

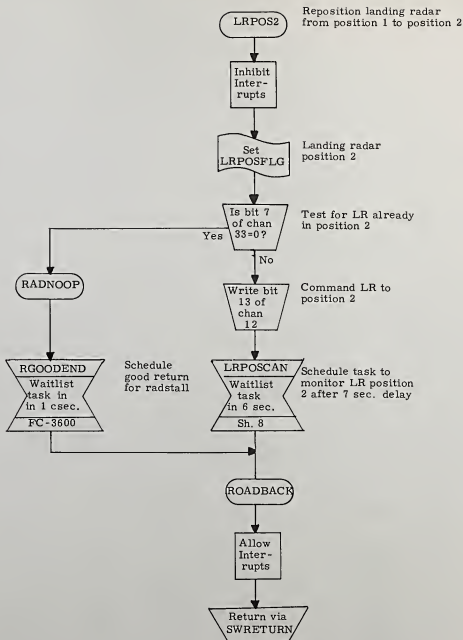


| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                |  | APOLLO GUIDANCE AND NAVIGATION       |                         |
|---|----------------|--|--------------------------------------|-------------------------|
| DRAWN <i>R. L. Litch</i>                    | <i>10/1/62</i> |  | R12 - Descent State<br>Vector Update |                         |
| PRGMR <i>R. M. Moore</i>                    | <i>10/1/62</i> |  |                                      |                         |
| ANALST                                      |                |  | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| DOCMR <i>W. D. Dwyer</i>                    | <i>10/1/62</i> |  | REV 0                                | SHEET 5 OF 36           |
| APPR'D <i>R. L. Litch</i>                   | <i>10/1/62</i> |  |                                      |                         |

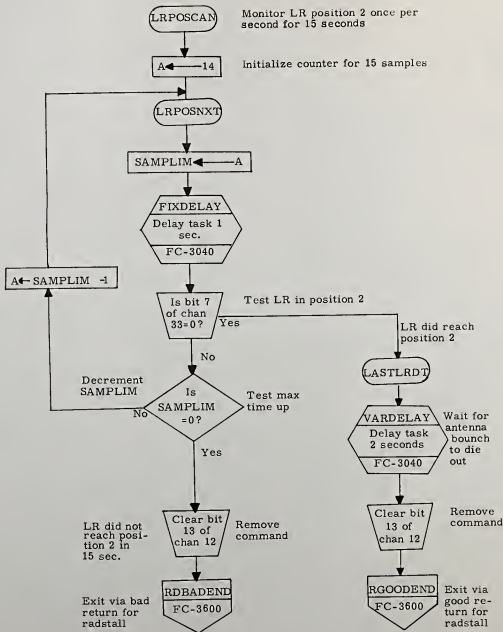


|   |  |                                      |               |
|---|--|--------------------------------------|---------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION       |               |
| DRAWN <i>G. Nichols</i> 10/2/65             |  | R12 - Descent State<br>Vector Update |               |
| PRGMR <i>B. Moore</i> 10/1/65               |  | DOCUMENT NO.                         |               |
| ANALST <i>W. English</i> 10/1/65            |  | LUMINARY 1C                          | FC-3935       |
| DOCMR <i>R. M. Fetter</i> 10/1/65           |  | REV 0                                | SHEET 6 OF 36 |

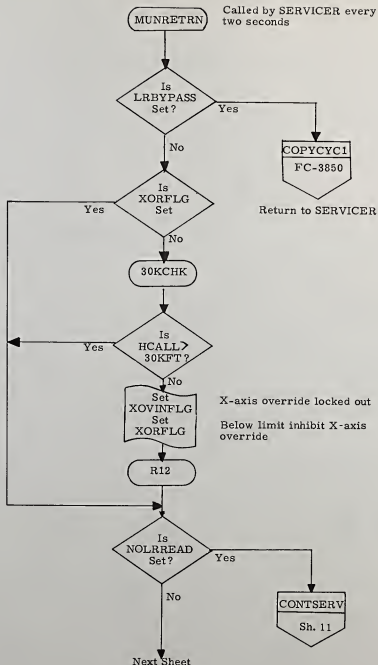




| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                    | APOLLO GUIDANCE AND NAVIGATION       |                         |
|---|--------------------|--------------------------------------|-------------------------|
| DRAWN                                       | <i>[Signature]</i> | R12 - Descent State<br>Vector Update |                         |
| PRGMR                                       | <i>[Signature]</i> | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| ANALST                                      |                    |                                      |                         |
| DOCNR                                       | <i>[Signature]</i> | REV 0                                | SHEET 7 OF 36           |
| APPR'D                                      | <i>[Signature]</i> |                                      |                         |

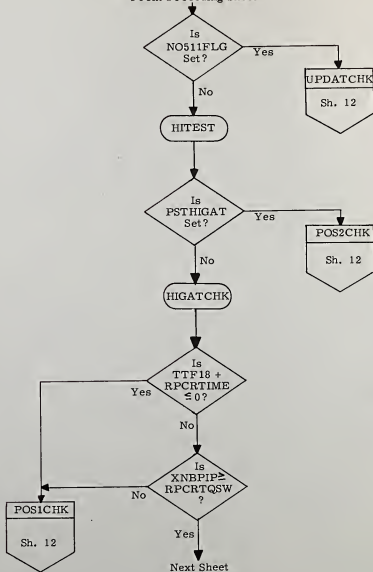


| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                | APOLLO GUIDANCE AND NAVIGATION       |               |
|---|----------------|--------------------------------------|---------------|
| DRAWN <i>R. L. Delcher</i>                  | <i>6/19/69</i> | R12 - Descent State<br>Vector Update |               |
| PRGMR <i>De Moore</i>                       | <i>6/16/69</i> | LUMINARY 1C                          | DOCUMENT NO.  |
| ANALST <i>W. B. Smith</i>                   | <i>1/10/69</i> |                                      | FC-3935       |
| DOCNR <i>W. B. Smith</i>                    | <i>1/10/69</i> | REV 0                                | SHEET 8 OF 36 |
| APPRO'D <i>R. M. Eubank</i>                 |                |                                      |               |



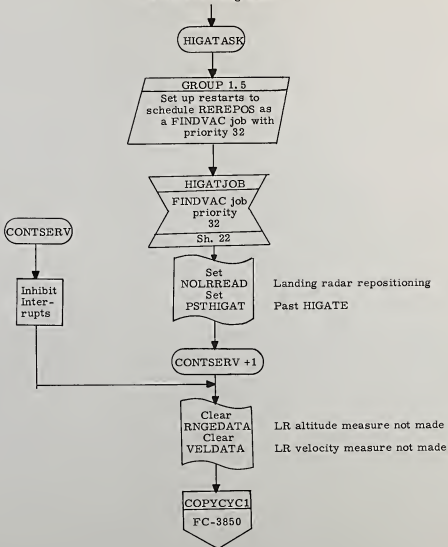
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                 | APOLLO GUIDANCE AND NAVIGATION       |                         |
|---|-----------------|--------------------------------------|-------------------------|
| DRAWN <i>R. L. G. L. G.</i>                 | <i>10/18/69</i> | R12 - Descent State<br>Vector Update |                         |
| PRGMR <i>R. Moore</i>                       | <i>10/1/69</i>  | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| ANALST                                      |                 |                                      |                         |
| DOCNR <i>M. D. G. L. G.</i>                 | <i>10/1/69</i>  | REV 0                                | SHEET 9 OF 36           |
| APPR'D <i>R. T. M. E. L. G.</i>             | <i>10/1/69</i>  |                                      |                         |

From Preceding Sheet



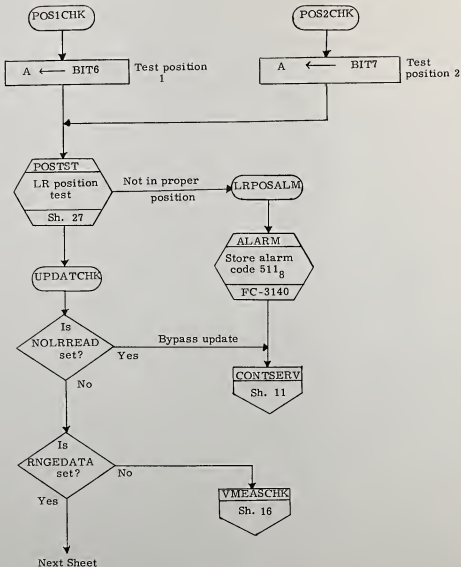
|   |       |                                      |                        |
|---|-------|--------------------------------------|------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |       | APOLLO GUIDANCE AND NAVIGATION       |                        |
| DRAWN <i>R. M. Smith</i> 12/29/68           |       | R12 - Descent State<br>vector Update |                        |
| PRGMR <i>R. M. Smith</i> 12/1/69            |       | MAIN BY JC                           | DOCUMENT NO.<br>C-3935 |
| ANALST                                      |       |                                      |                        |
| DOCNR <i>R. M. Smith</i> 12/5/69            |       |                                      |                        |
| APPR'D <i>R. M. Smith</i> 12/11/69          | REV 0 | SHEET 10 OF 36                       |                        |

From Preceding Sheet

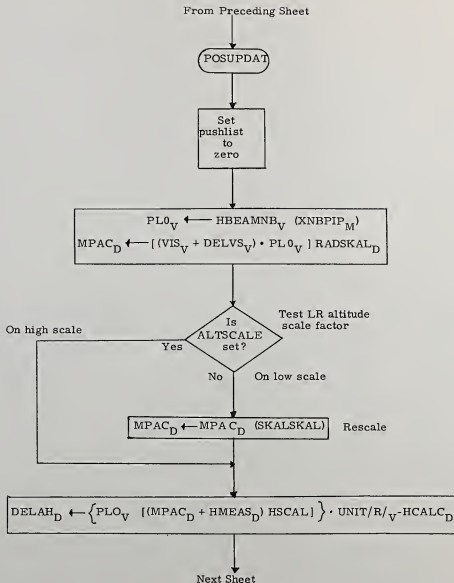


Return to SERVICER

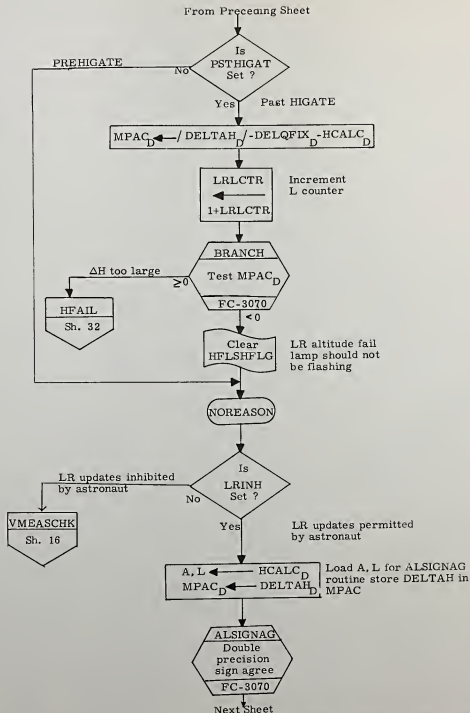
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |               | APOLLO GUIDANCE AND NAVIGATION       |                |
|---|---------------|--------------------------------------|----------------|
| DRAWN <i>R. Welch</i>                       | <i>4/1/69</i> | R12 - Descent State<br>Vector Update |                |
| PRGMR <i>L. Moore</i>                       | <i>4/1/69</i> | LUMINARY 1C                          | DOCUMENT NO.   |
| ANALST                                      |               |                                      | FC-3935        |
| DOCMR <i>M. Dwyer</i>                       | <i>4/1/69</i> | REV 0                                | SHEET 11 OF 38 |
| APPR'D <i>R.M. Estes</i>                    | <i>4/1/69</i> |                                      |                |



|   |  |                                      |  |
|---|--|--------------------------------------|--|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION       |  |
| DRAWN <i>G. L. White</i> 11/23/69           |  | R12 - Descent State<br>Vector Update |  |
| PRGMR <i>G. Moore</i> 11/11/69              |  | DOCUMENT NO.<br>C-3935               |  |
| ANALST <i>H. B. White</i> 11/24/69          |  | J. UMINAR 1C                         |  |
| DOCMR <i>R. M. Foster</i> 11/24/69          |  | REV 0                                |  |
|   |  | SHEET 12 OF 36                       |  |

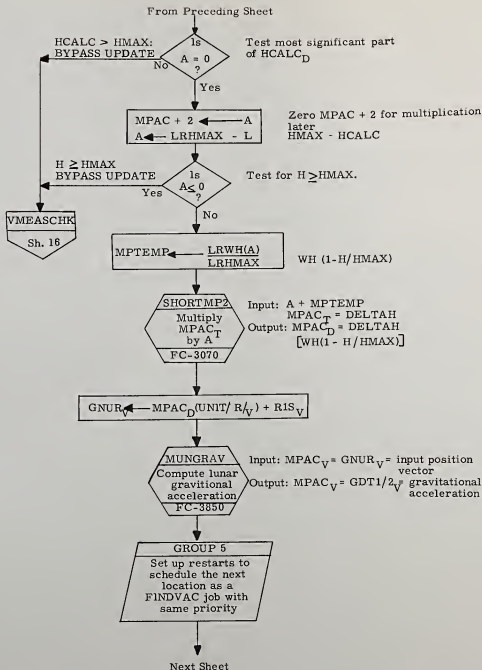


|   |  |                                      |                         |
|---|--|--------------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION       |                         |
| DRAWN <i>G. L. White</i> <i>12/1/67</i>     |  | R12 - Descent State<br>Vector Update |                         |
| PRGMR <i>R. Moore</i> <i>12/1/67</i>        |  | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| ANALST <i>W. D. Smith</i> <i>12/1/67</i>    |  |                                      |                         |
| APPR'D <i>R. M. Evans</i> <i>12/1/67</i>    |  | REV 0                                | SHEET 13 OF 36          |



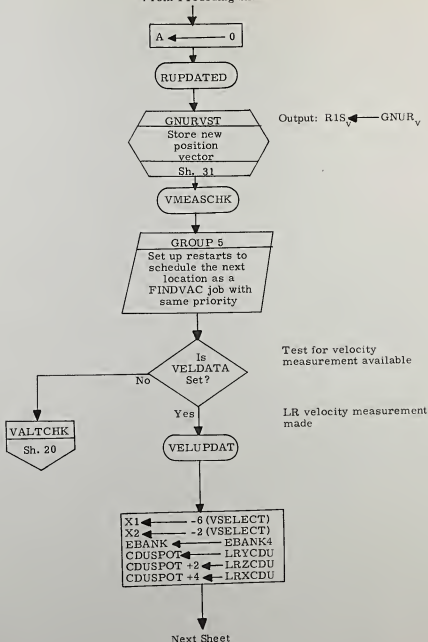
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| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION    |  |
| DRAWN <i>R. Welch</i> 11/16/69              |  | R12 - Descent State Vector Update |  |
| PRGMR <i>R. Moore</i> 11/16/69              |  | DOCUMENT NO. FC-3935              |  |
| ANALST <i>R. DeFord</i> 11/24/69            |  | LUMINARY 1C                       |  |
| DOCMR <i>R. DeFord</i> 12/1/69              |  | REV 0                             |  |
| APPRO'D <i>R. DeFord</i> 12/1/69            |  | SHEET 14 OF 36                    |  |





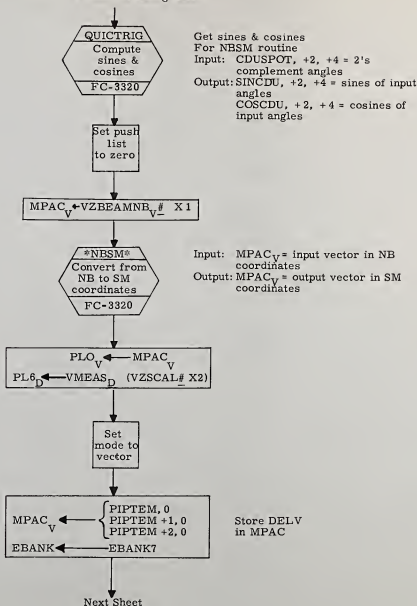
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                | APOLLO GUIDANCE AND NAVIGATION       |                |
|---|----------------|--------------------------------------|----------------|
| DRAWN <i>R. L. White</i>                    |                | R12 - Descent State<br>Vector Update |                |
| PRGMR <i>R. L. White</i>                    | <i>12/1/69</i> | DOCUMENT NO.                         |                |
| ANALST <i>R. L. White</i>                   | <i>12/1/69</i> | UMINARY 1C                           | FC-3935        |
| DOCMR <i>R. L. White</i>                    | <i>12/1/69</i> | REV 0                                | SHEET 15 OF 36 |

From Preceding Sheet



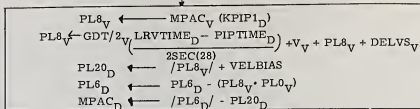
|   |  |                                   |               |
|---|--|-----------------------------------|---------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION    |               |
| DRAWN <i>B. Welch</i> 11/19/68              |  | R12 - Descent State Vector Update |               |
| PRGMR <i>B. Welch</i> 11/19/68              |  | DOCUMENT NO.                      |               |
| ANALST <i>B. Welch</i> 11/19/68             |  | APOLLO 11C                        | 11C-3935      |
| DOCMR <i>B. Welch</i> 11/19/68              |  | REV 0                             | SHEET 1 OF 38 |
| APPR'D <i>R. P. ...</i> 11/19/68            |  |                                   |               |

From Preceding Sheet



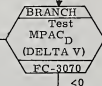
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                | APOLLO GUIDANCE AND NAVIGATION       |                |
|---|----------------|--------------------------------------|----------------|
| DRAWN <i>R. Welch</i>                       | <i>12/1/69</i> | R12 - Descent State<br>Vector Update |                |
| PRGMR <i>R. Welch</i>                       | <i>12/1/69</i> | LUMINARY 1C                          | DOCUMENT NO.   |
| ANALST <i>R. Welch</i>                      | <i>12/1/69</i> |                                      | FC-3935        |
| DOCMR <i>R. Welch</i>                       | <i>12/1/69</i> | REV 0                                | SHEET 17 OF 36 |
| APPR'D <i>R. M. Foster</i>                  | <i>12/1/69</i> |                                      |                |

From Preceding Sheet



Increment  
M counter

Delta V ≥ 0



LR velocity fail lamp  
should not be flashing

Update X-axis velocity



Test for update of  
X-axis velocity

No

Yes



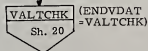
Update X-axis velocity



Bypass velocity update

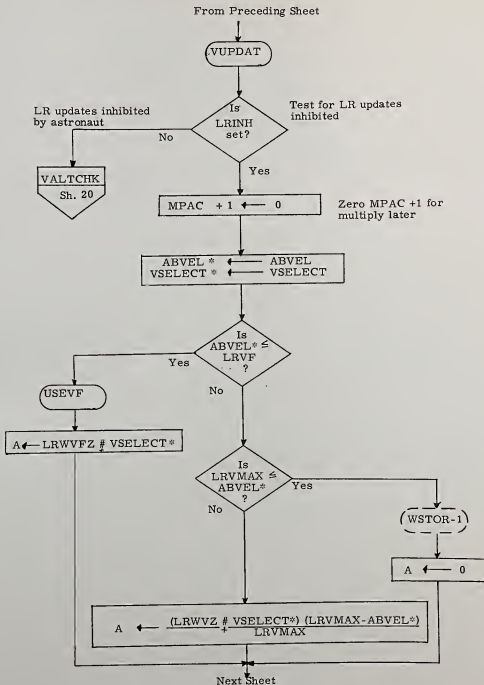
Yes

No

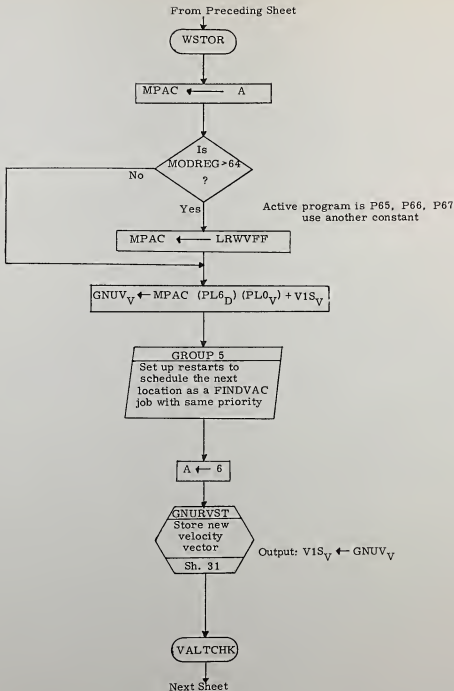


Next Sheet

| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                    |                 | APOLLO GUIDANCE AND NAVIGATION       |                |
|---|--------------------|-----------------|--------------------------------------|----------------|
| DRAWN                                       | <i>G. D. White</i> | <i>10/26/68</i> | R12 - Descent State<br>Vector Update |                |
| PRGRM                                       | <i>R. Stone</i>    | <i>10/1/69</i>  | LUMINARY 1C                          | DOCUMENT NO.   |
| ANALST                                      | <i>W. D. White</i> | <i>10/26/69</i> |                                      | FC-3935        |
| DOCNR                                       | <i>W. D. White</i> | <i>10/26/69</i> | REV 0                                | SHEET 18 OF 36 |
| APPR'D                                      | <i>R. M. Stone</i> | <i>12/11/69</i> |                                      |                |

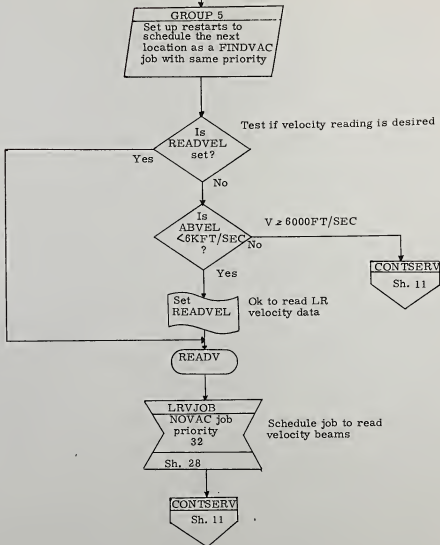


|   |  |                                      |  |
|---|--|--------------------------------------|--|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION       |  |
| DRAWN <i>G. L. White</i> 10/24/69           |  | R12 - Descent State<br>Vector Update |  |
| PRGRM <i>LRVU</i> 10/1/69                   |  | DOCUMENT NO.<br>FC-3935              |  |
| ANALST <i>W. D. Burdick</i> 10/26/69        |  | LUMINARY 1C                          |  |
| DOCNR <i>FC-3935</i> 10/26/69               |  | REV 0                                |  |
| *****                                       |  | SHEET 19 OF 38                       |  |

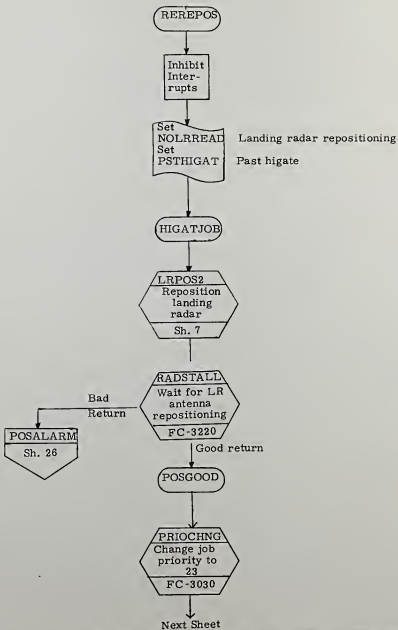


|   |                   |                 |                                      |                         |
|---|-------------------|-----------------|--------------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                   |                 | APOLLO GUIDANCE AND NAVIGATION       |                         |
| DRAWN                                       | <i>R. Nichols</i> | <i>11/25/69</i> | R12 - Descent State<br>Vector Update |                         |
| PRGMR                                       | <i>R. Nichols</i> | <i>12/1/69</i>  | LUMINARY 1C                          | DOCUMENT NO.<br>1C-3933 |
| ANALST                                      |                   |                 |                                      |                         |
| DOCMR                                       | <i>R. Nichols</i> | <i>11/25/69</i> | REV 0                                | SHEET 20 OF 36          |
| APPR'D                                      | <i>R. Nichols</i> | <i>12/1/69</i>  |                                      |                         |

From Preceding Sheet

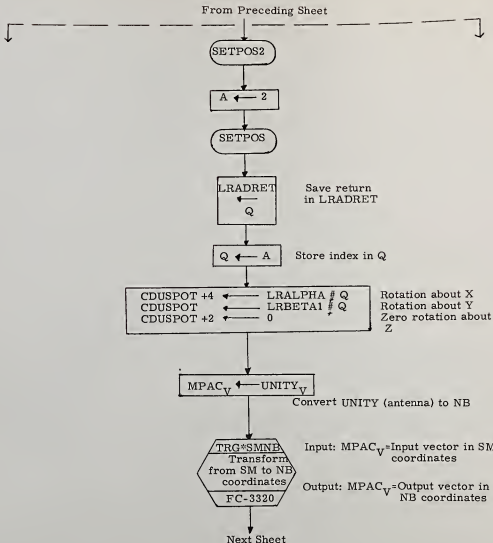


| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                          | APOLLO GUIDANCE AND NAVIGATION       |              |
|---|--------------------------|--------------------------------------|--------------|
| DRAWN                                       | <i>P. Linker</i> 1/12/69 | R12 - Descent State<br>Vector Update |              |
| PRGMR                                       | <i>P. Massie</i> 1/11/69 | LUMINARY 1C                          | DOCUMENT NO. |
| ANALST                                      |                          |                                      | FC-3935      |
| DOCMR                                       | <i>P. Linker</i> 1/12/69 | REV 0                                |              |
| DATE  | 12/1/69                  |                                      |              |
|   |                          | SHEET 21 OF 36                       |              |

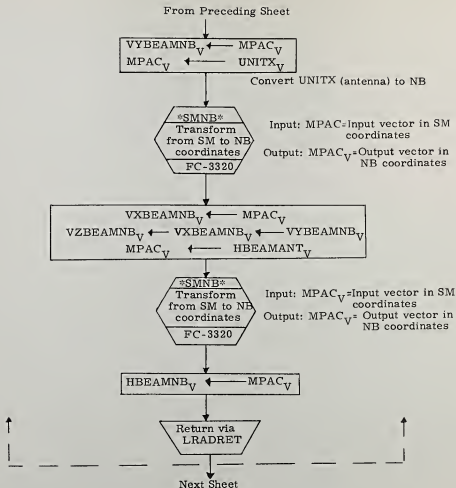


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|---|-------------------|-----------------------------------|----------------|
| DRAWN                                       | <i>R. L. Dale</i> | R12 - Descent State Vector Update |                |
| PRGMR                                       | <i>R. Moore</i>   | DOCUMENT NO.                      |                |
| ANALST                                      | <i>R. Moore</i>   | LUMINARY 1C                       | FC-3935        |
| DOCMR                                       | <i>R. Moore</i>   | REV 0                             | SHEET 22 OF 35 |
| APPR'D                                      | <i>R. Moore</i>   |                                   |                |





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|---|----------|--------------------------------------|-------------------------|
| DRAWN <i>G. W. White</i>                    | 10/29/68 | R12 - Descent State<br>Vector Update |                         |
| PRGMR <i>D. Moore</i>                       | 10/1/69  | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| ANALST                                      |          |                                      |                         |
| DOCMR <i>W. G. Foster</i>                   | 10/29/68 | REV 0                                |                         |
| APPR'D <i>D. W. White</i>                   | 12/1/69  | SHEET 23 OF 36                       |                         |



|   |                 |                                      |                         |
|---|-----------------|--------------------------------------|-------------------------|
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| DRAWN                                       | <i>B. White</i> | R12 - Descent State<br>Vector Update |                         |
| PRGMR                                       | <i>R. Moore</i> |                                      |                         |
| ANALST                                      |                 | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| DOCMR                                       | <i>R. Moore</i> |                                      |                         |
| APPR'D                                      | <i>R. Moore</i> | REV 0                                | SHEET 24 OF 36          |

From Preceding Sheet

Set  
LPOS2FLG

Use LR position 2  
transformation

ENDPOS

Clear  
NOLRREAD

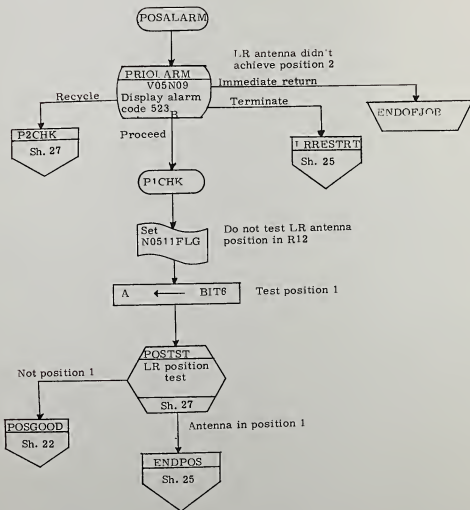
Landing radar not  
repositioning

LRRESTR1

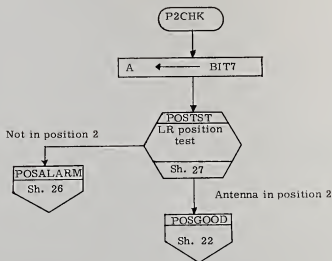
GROUP 1, 0  
Kill group  
1 restarts

ENDOFJOB

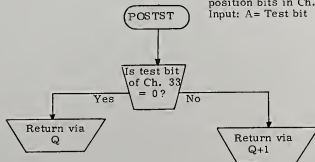
|   |       |                                      |                         |
|---|-------|--------------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |       | APOLLO GUIDANCE AND NAVIGATION       |                         |
| DRAWN <i>B. White</i> 12/1/69               |       | R12 - Descent State<br>Vector Update |                         |
| PRGMR <i>B. White</i>                       |       | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| ANALST <i>B. White</i>                      |       |                                      |                         |
| DOCMR <i>B. White</i>                       |       |                                      |                         |
| APPR'D <i>B. White</i> 12/1/69              | REV 0 | SHEET 25 OF 35                       |                         |



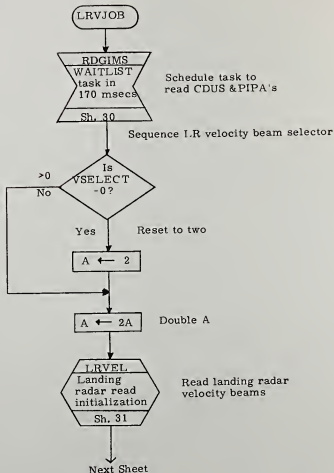
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                    | APOLLO GUIDANCE AND NAVIGATION       |                         |
|---|--------------------|--------------------------------------|-------------------------|
| DRAWN                                       | <i>G. Webb</i>     | R12 - Descent State<br>Vector Update |                         |
| PRGMR                                       | <i>Donner</i>      |                                      |                         |
| ANALST                                      |                    | LUMINARY IC                          | DOCUMENT NO.<br>FC-3935 |
| DOCMR                                       | <i>W. B. Smith</i> |                                      |                         |
| APPR'D                                      | <i>R. M. Felt</i>  | REV 0                                | SHEET 26 OF 38          |



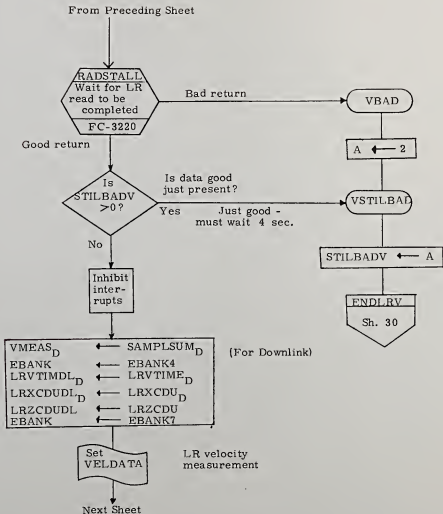
Subroutine to test LR  
position bits in Ch. 33  
Input: A = Test bit



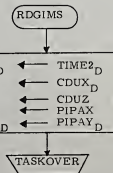
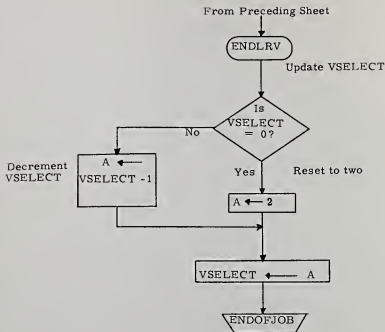
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION       |  |
|---|--|--------------------------------------|--|
| DRAWN: <i>[Signature]</i> 1/10/69           |  | R12 - Descent State<br>vector Update |  |
| PRGMR: <i>[Signature]</i> 1/10/69           |  | DOCUMENT NO.<br>12-005               |  |
| ANALST: <i>[Signature]</i> 1/10/69          |  | REVISION: 1C                         |  |
| DOCMR: <i>[Signature]</i> 1/10/69           |  | SHEET 2 OF 36                        |  |
| APPR'D: <i>[Signature]</i> 1/10/69          |  | REVISION: 0                          |  |



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|---|---------------------|----------------|--------------------------------------|-------------------------|
| DRAWN                                       | <i>P. Walch</i>     | <i>10/1/69</i> | R12 - Descent State<br>Vector Update |                         |
| PRGMR                                       | <i>B. Moore</i>     | <i>10/1/69</i> |                                      |                         |
| ANALST                                      |                     |                | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| DOCMR                                       | <i>H. Dwyer</i>     | <i>10/2/69</i> |                                      |                         |
| APPR'D                                      | <i>R. M. Foster</i> | <i>12/1/69</i> | REV 0                                | SHEET 28 OF 36          |

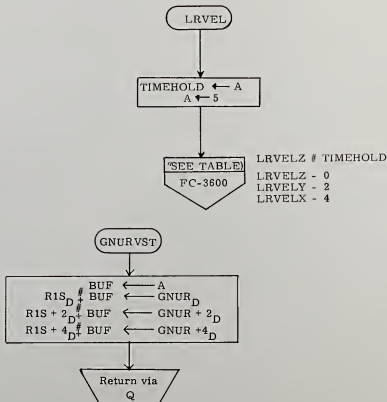


|   |         |                                      |  |
|---|---------|--------------------------------------|--|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |         | APOLLO GUIDANCE AND NAVIGATION       |  |
| DRAWN <i>R. White</i> 12/1/69               |         | R12 - Descent State<br>Vector Update |  |
| PRGMR <i>R. White</i>                       | 12/1/69 | DOCUMENT NO.<br>FC-3935              |  |
| ANALST <i>H. Bank</i>                       | 12/1/69 | LUMINARY 1C                          |  |
| DOCMR <i>H. Bank</i>                        | 12/1/69 | REV 0                                |  |
| APPR'D <i>R. White</i>                      | 12/1/69 | SHEET 29 OF 36                       |  |

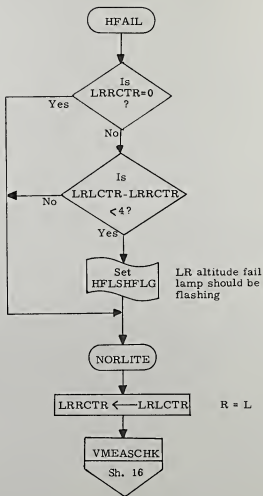


|   |                     |                |                                      |                         |
|---|---------------------|----------------|--------------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                     |                | APOLLO GUIDANCE AND NAVIGATION       |                         |
|   |                     |                | R12 - Descent State<br>Vector Update |                         |
| DRAWN                                       | <i>B. White</i>     | <i>1/25/69</i> |                                      |                         |
| PRGMR                                       | <i>B. White</i>     | <i>1/25/69</i> | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| ANALST                                      |                     |                |                                      |                         |
| DOCNR                                       | <i>W. Byrd</i>      | <i>1/25/69</i> |                                      |                         |
| APPR'D                                      | <i>R. M. Foster</i> | <i>1/25/69</i> |                                      |                         |
|   |                     |                | REV 0                                | SHEET 30 OF 36          |

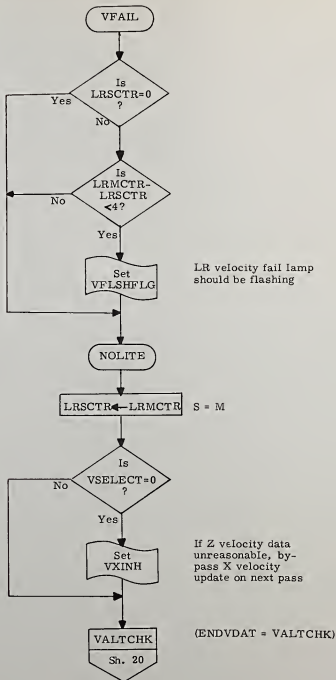




| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                | APOLLO GUIDANCE AND NAVIGATION       |                         |
|---|----------------|--------------------------------------|-------------------------|
| DRAWN <i>R. Welch</i>                       | <i>10/1/69</i> | R12 - Descent State<br>Vector Update |                         |
| PRGMR <i>R. Moore</i>                       | <i>10/1/69</i> |                                      |                         |
| ANALST <i>M. Wright</i>                     | <i>10/1/69</i> | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| DOCMR <i>R. Moore</i>                       | <i>10/1/69</i> | REV 0                                | SHEET 31 OF 38          |



| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                | APOLLO GUIDANCE AND NAVIGATION       |                         |
|---|----------------|--------------------------------------|-------------------------|
| DRAWN <i>J. Walsh</i>                       | <i>12/1/69</i> | R12 - Descent State<br>Vector Update |                         |
| PRGMR <i>Donner</i>                         | <i>12/1/69</i> | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| ANALST                                      |                |                                      |                         |
| DOCNR <i>11-22-69</i>                       | <i>12/1/69</i> | REV 0                                |                         |
| APPR'D <i>R. M. Egan</i>                    | <i>12/1/69</i> | SHEET 32 OF 36                       |                         |



| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                  | APOLLO GUIDANCE AND NAVIGATION       |                         |
|---|------------------|--------------------------------------|-------------------------|
| DRAWN <i>B. Walsh</i>                       | <i>4/14/69</i>   | R12 - Descent State<br>Vector Update |                         |
| PRGRM <i>B. Moore</i>                       | <i>5/1/69</i>    | LUMINARY 1C                          | DOCUMENT NO.<br>FC-3935 |
| ANALST                                      |                  |                                      |                         |
| DOCMR <i>H. H. H. H.</i>                    | <i>4/7/69</i>    |                                      |                         |
| APPR'D <i>ROY D. ...</i>                    | <i>(3/11/69)</i> | REV 0                                | SHEET 33 OF 36          |

| Subroutine | Flowchart | Description                                | Where Called  |
|------------|-----------|--|---------------|
| TESTXACT   | FC-3100   | Test for extended verb active              | Sh. 2         |
| 2SECDLY    | FC-3050   | Delay job 2 seconds                        | Sh. 3         |
| RADSTALL   | FC-3220   | Wait for end of radar routine              | Sh. 5, 22, 29 |
| ALARM      | FC-3140   | Store alarm code                           | Sh. 5, 12     |
| FIXDELAY   | FC-3040   | Delay task 1 second                        | Sh. 8         |
| VARDELAY   | FC-3040   | Delay task 2 seconds                       | Sh. 8         |
| BRANCH     | FC-3070   | Test MPAC <sub>D</sub>                     | Sh. 14, 18    |
| ALSIGNAG   | FC-3070   | Double precision sign agree                | Sh. 14        |
| SHORTMP2   | FC-3070   | Multiply MPAC <sub>T</sub>                 | Sh. 15        |
| MUNGRAV    | FC-3850   | Compute lunar gravitation acceleration     | Sh. 15        |
| QUICCTRIG  | FC-3320   | Compute sines and cosines                  | Sh. 17        |
| *NBMS*     | FC-3320   | Transform vector from NB to SM coordinates | Sh. 17        |
| PROCHNG    | FC-3030   | Change job priority                        | Sh. 22        |
| TRG*SMNB   | FC-3320   | Transform vector from SM to NB coordinates | Sh. 23        |
| *SMNB*     | FC-3320   | Transform vector from SM to NB coordinates | Sh. 24        |

|   |         |                                      |                |
|---|---------|--------------------------------------|----------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |         | APOLLO GUIDANCE AND NAVIGATION       |                |
| DRAWN <i>D</i>                              |         | R12 - Descent State<br>Vector Update |                |
| PRGMR <i>D Moore</i>                        | 12/1/69 | LUMINARY 1C                          | DOCUMENT NO.   |
| ANALST                                      |         |                                      | FC-3935        |
| DOCMR <i>W. Dwyer</i>                       | 1/25/67 | REV 0                                | SHEET 34 OF 36 |
| APPR'D <i>R.M. Carter</i>                   | 12/1/69 |                                      |                |

# FLAGS

| Name                       | Meaning When Set                    | Meaning When Cleared                | Where Set  | Where Cleared | Where Tested |
|----------------------------|-------------------------------------|-------------------------------------|------------|---------------|--------------|
| LRINH<br>FLAG 11 BIT 8     | LR updates permitted by astronaut   | LR updates inhibited by astronaut   | Sh. 2      | Sh. 3, 4      | Sh. 14, 19   |
| NOR29FLG<br>FLAG 3 BIT 11  | R29 not allowed                     | R29 allowed                         |            |               | Sh. 6        |
| R77FLG<br>FLAG 5 BIT 11    | R77 is on                           | R is not on                         |            |               | Sh. 6        |
| V37FLG<br>FLAG 7 BIT 6     | Average (SERVICER) running          | Average (SERVICER) off              |            |               | Sh. 6        |
| LRBYPASS<br>FLAG 11 BIT 15 | Bypass all landing radar updates    | Do not bypass landing radar updates |            |               | Sh. 6, 9     |
| TRACKFLG<br>FLAG 1 BIT 5   | Tracking allowed                    | Tracking not allowed                |            |               | Sh. 6        |
| LRPOSFLG<br>FLAG 12 BIT 6  | Landing radar position 2            | Landing radar position 1            |            |               | Sh. 7        |
| XORFLG<br>FLAG 11 BIT 9    | Below limit inhibit X-axis override | Above limit do not inhibit          | Sh. 9      |               | Sh. 9        |
| XOVINFLG<br>FLAG 13 BIT 9  | X-axis override locked out          | X-axis override okay                | Sh. 9      |               |              |
| NOLRREAD<br>FLAG 11 BIT 10 | LR repositioning; bypass update     | LR not repositioning                | Sh. 11, 22 | Sh. 25        | Sh. 9, 12    |

|   |                     |                                      |  |
|---|---------------------|--------------------------------------|--|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                     | APOLLO GUIDANCE AND NAVIGATION       |  |
| DRAWN                                       |                     | R12 - Descent State<br>Vector Update |  |
| PRGMR                                       | <i>R. Moore</i>     | 11/1/69                              |  |
| ANALST                                      |                     |                                      |  |
| DOCMR                                       | <i>W. Daghack</i>   | 11/25/69                             |  |
| APPR'D                                      | <i>R. M. E. ...</i> | 12/1/69                              |  |
| LUMINARY IC                                 |                     | DOCUMENT NO.<br>FC-3935              |  |
| REV 0                                       |                     | SHEET 35 OF 36                       |  |

FLAGS (CONTINUED)

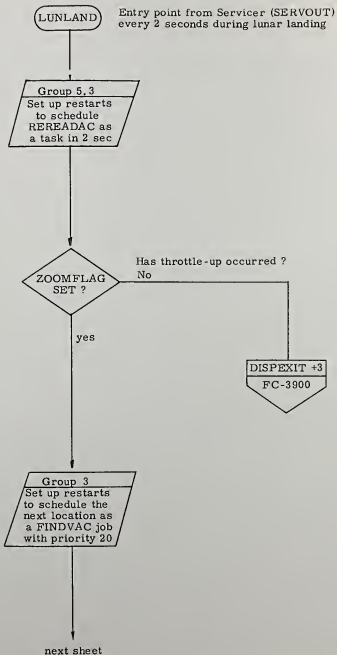
| Name                       | Meaning When Set                         | Meaning When Cleared                         | Where Set  | Where Cleared | Where Tested |
|----------------------------|--|--|------------|---------------|--------------|
| NO511FLG<br>FLAG 11 BIT 3  | Do not test LR antenna position in R12   | Test LR antenna position in R12              | Sh. 26     |               | Sh. 10       |
| PSTHIGAT<br>FLAG 11 BIT 11 | Past higate                              | Pre higate                                   | Sh. 11, 22 |               | Sh. 10, 14   |
| RNGEDATA<br>FLAG 11 BIT 4  | LR altitude measurement made             | LR altitude measurement not made             |            | Sh. 11        | Sh. 12       |
| VELDATA<br>FLAG 11 BIT 7   | LR velocity measurement made             | LR velocity measurement not made             |            | Sh. 11        | Sh. 16       |
| ALTSCALE<br>FLAG 12 BIT 9  | LR altitude reading is on high scale     | LR altitude reading is on low scale          | Sh. 29     |               | Sh. 13       |
| HFLSHFLG<br>FLAG 11 BIT 1  | LR altitude fail lamp should be flashing | LR altitude fail lamp should not be flashing | Sh. 32     | Sh. 14        |              |
| VXINH<br>FLAG 11 BIT 12    | Bypass X velocity update on next pass    | Update X-axis velocity                       | Sh. 33     | Sh. 18        | Sh. 18       |
| READVEL<br>FLAG 11 BIT 5   | Ok to read LR velocity data              | Do not read LR velocity data                 | Sh. 21     |               |              |
| LPOS2FLG<br>FLAG 11 BIT 6  | Use LR position 2 transformation         | Use LR position 1 transformation             | Sh. 25     |               |              |
| VFLSHFLG<br>FLAG 11 BIT 2  | LR velocity fail lamp should be flashing | LR velocity fail lamp should not be flashing | Sh. 33     |               |              |

|   |                   |                                      |  |
|---|-------------------|--------------------------------------|--|
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| DRAWN                                       |                   | R12 - Descent State<br>Vector Update |  |
| PRGMR                                       | <i>DM</i>         | 12/1/69                              |  |
| ANALST                                      |                   |                                      |  |
| DOCMR                                       | <i>W. English</i> | 11/25/69                             |  |
| APPR'D                                      | <i>RCM</i>        | 12/1/69                              |  |
| LUMINARY IC                                 |                   | DOCUMENT NO.<br>FC-3935              |  |
| REV 0                                       |                   | SHEET 36 OF 36                       |  |

R13 - Landing Auto Modes Monitor

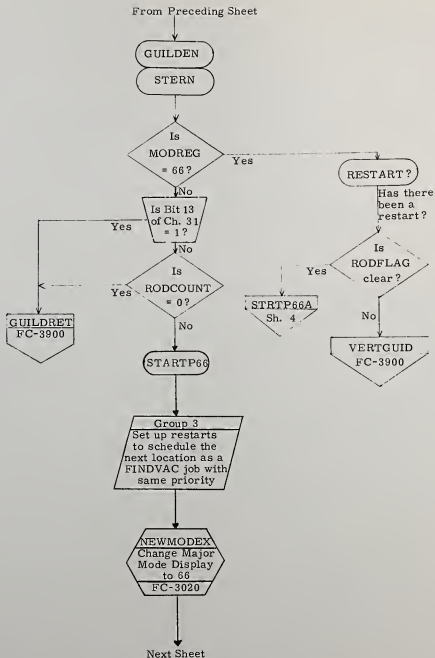
LUNLAND Sh. 2  
DESCBITS Sh. 6

|   |                 |                                |                         |
|---|-----------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                 | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN <i>G. L. Walch</i>                    | <i>12/4/69</i>  | Landing Auto Modes Monitor     |                         |
| PRGMR <i>G. Walch</i>                       | <i>12/4/69</i>  |                                |                         |
| ANALST                                      |                 | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3940 |
| DOCMR <i>W. D. Dwyer</i>                    | <i>12/15/69</i> |                                |                         |
| APPR'D <i>W. D. Dwyer</i>                   | <i>12/16/69</i> | REV 1                          | SHEET 1 OF 7            |



|   |  |                                |              |
|---|--|--------------------------------|--------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |  | APOLLO GUIDANCE AND NAVIGATION |              |
| DRAWN <i>D. Lutz</i> 8-14-68                |  | Landing Auto Modes Monitor     |              |
| PRGMR <i>D. Lutz</i> 8-14-68                |  | DOCUMENT NO.                   |              |
| ANALYST                                     |  | LUMINARY 1C                    | FC-3940      |
| DOCMR <i>W.C. DANFORTH</i>                  |  | REV 1                          | SHEET 2 OF 7 |
| APPR'D <i>W.C. Danforth</i>                 |  |                                |              |





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|---|---------|--------------------------------|-------------------------|--|
| DRAWN <i>L. Haldeman</i>                    | 12/2/69 | Landing Auto Modes Monitor     |                         |  |
| PRGMR <i>P. Gullen</i>                      | 12/2/69 | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3940 |  |
| ANALST                                      |         |                                |                         |  |
| DCMR <i>W.C. Dwyer</i>                      | 1/10/69 | REV 1 SHEET 3 OF 7             |                         |  |
| APPR <i>W.C. Dwyer</i>                      | 1/10/69 |                                |                         |  |

From Preceding Sheet

$VDGVERT_D \leftarrow HDOTDISP_D$

Set desired altitude rate  
= current altitude rate

STRTP66A

$MPAC_V \leftarrow PBIASX, PBIASZ, PBIASZ$   
 $VBIAS_V \leftarrow MPAC_V (BIASFACT)$

$BIASFACT = 655.36 \times 2^{-26}$

Set  
RODFLAG

If in P66, normal operation  
continues. Restart clears flag.

$OLDPIPAX_V \leftarrow TEMX_V$   
 $DELVRD_V \leftarrow 0_V$   
 $RODSCAL_D \leftarrow RODSCALE_D$   
 $LASTTHP_D \leftarrow PTIME_D$   
 $FCOLD \leftarrow 0$   
 $FWIGHT \leftarrow 0$   
 $FWIGHT +1 \leftarrow 0$

Next Sheet

|   |                   |                                |                         |
|---|-------------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                   | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN                                       |                   | Landing Auto Modes Monitor     |                         |
| PRGMR                                       | <i>P. Collier</i> | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3940 |
| ANALST                                      |                   |                                |                         |
| DOCMR                                       | <i>W.C. Dwyer</i> |                                |                         |
| APPR'D                                      | <i>W.C. Dwyer</i> | REV 1                          | SHEET 4 OF 4            |

From Preceding Sheet

WCHVERT + 2  
WCHPHOLD + 2  
WCHPHASE + 2

STOPRATE  
Zero inputs  
to Autopilot  
FC-3430

Zero incremental angles,  
rates and biases for roll,  
pitch and yaw

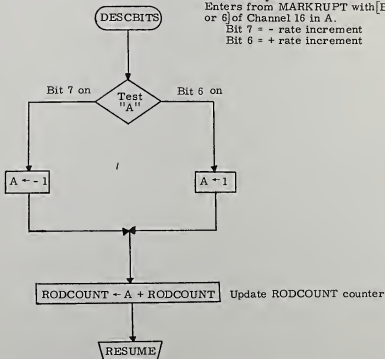
Clear  
XOVINFLG,  
REDFLAG

X-axis override OK  
Landing site redesignation  
not permitted

VERTGUID  
FC-3900

|   |                         |                                |  |
|---|-------------------------|--------------------------------|--|
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| DRAWN                                       |                         | Landing Auto Modes Monitor     |  |
| PRGMR                                       | <i>R. Allen</i>         | DOCUMENT NO.<br>FC-3940        |  |
| ANALST                                      |                         | LUMINARY 1C                    |  |
| DOCMR                                       | <i>H.C. Dyer</i>        | REV 1                          |  |
| APPR'D                                      | <i>Alfred J. Somers</i> | SHEET 5 OF 7                   |  |

Subroutine to update RODCOUNT with  
output from rate of descent switch  
activated by astronaut  
Enters from MARKRUPT with [Bit 7  
or 6] of Channel 16 in A.  
Bit 7 = - rate increment  
Bit 6 = + rate increment



|   |                    |                                |                         |
|---|--------------------|--------------------------------|-------------------------|
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| DRAWN                                       |                    | Landing Auto Modes Monitor     |                         |
| PRGMR                                       | <i>R. Keller</i>   | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3940 |
| ANALST                                      | <i>H. C. Smith</i> |                                |                         |
| DOCMR                                       | <i>H. C. Smith</i> | REV 1                          | SHEET 5 OF 7            |

## SUBROUTINES CALLED ON OTHER FLOWCHARTS

| Subroutine | Flowchart | Description               | Where Called |
|------------|-----------|---------------------------|--------------|
| DISPEXIT   | FC-3900   | Lunar Landing Entry Point | Sh. 2        |
| GUILDRET   | FC-3900   | Lunar Landing Entry Point | Sh. 3        |
| VERTGUID   | FC-3900   | Lunar Landing Entry Point | Sh. 3, 5     |
| NEWMODEX   | FC-3020   | Change Major Mode Display | Sh. 3        |
| STOPRATE   | FC-3430   | Zero Inputs To Autopilot  | Sh. 5        |

## FLAGS

| Name                      | Meaning When Set                      | Meaning When Cleared                     | Which Set | Where Cleared | Where Tested |
|---------------------------|---------------------------------------|--|-----------|---------------|--------------|
| ZOOMFLAG<br>Flag 5, Bit 8 | Throttle-up has occurred in P63       | Throttle-up has not occurred in P63      |           |               | Sh. 2        |
| RODFLAG<br>Flag 1 Bit 12  | If in P66, normal operation continues | If in P66 reinitialization is performed  | Sh. 4     |               | Sh. 3        |
| XOVINFLG<br>Flag 13 Bit 9 | X-axis override locked out            | X-axis override permitted                |           | Sh. 5         |              |
| REDFLAG<br>Flag 6 Bit 6   | Landing site redesignation permitted  | Landing site redesignation not permitted |           | Sh. 5         |              |

|   |                |                                |                         |
|---|----------------|--------------------------------|-------------------------|
| MIT INSTRUMENTATION LAB<br>CAMBRIDGE, MASS. |                | APOLLO GUIDANCE AND NAVIGATION |                         |
| DRAWN <i>M. Connor</i>                      | <i>12/7</i>    | Landing Auto Modes Monitor     |                         |
| PRGMR                                       |                |                                |                         |
| ANALST                                      |                |                                |                         |
| DOCMR <i>W.D. Galt</i>                      | <i>12/6/69</i> | LUMINARY 1C                    | DOCUMENT NO.<br>FC-3940 |
| APPR'D                                      |                | REV 1                          | SHEET 7 OF 7            |